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Studies on cytoplasmic-genetic male sterility of cultivated rice (*Oryza sativa* L.)[1]

II. Morphological-histological investigation on functional male sterility

Yu-Kuei Cheng[2] and Chen-Seng Huang[3]

Abstract : Anther indehiscence was the main cause of cytoplasmic-genetic male sterility for rices 65 P 2, 61 P 1 and KR 7. This type of male sterility, determined by cytoplasm and not by nucleus, was rather stable in a range of temperatures. The most significant difference of indehiscent anthers from normal ones is their strongly thickened-fibrous endothecium and their particular orientation pattern. The epidermal cells were also slightly thick-walled. Therefore the separation of intermicrosporangial stripe 1 (IMS 1) from the underlying parenchyma along each side of the connective tissue did not occur at anthesis. The outer surface of IMS 1 of indehiscent anther had some spurs or ridges whereas the surface of normal anthers was smooth. It may prevent the anthers to form anterior pore and pollen shedding. From these results, it is suggested that the anther wall structures and physical process of cohesion mechanism may be involved in anther dehiscence. The functional male sterility of rice is advantageous in that it can be propogated by compulsive self-pollination. Its possible use in developing hybrid rice was discussed.

In the previous paper [3], the present authors reported that anther indehiscence was the main cause of male sterility for rice plants having Pai-co cytoplasm (65 P 2, 61 P 1) and *O. rufipogon* cytoplasm (KR 7) regardless of temperature treatments. It is not determined by nuclear gene but is transmitted from generation to generation through egg cytoplasm. This type of sterility differs from other forms of sterility in that the plants produce normal amounts of viable pollen grains but the anthers do not open, and thus no pollen is shed as a result of defective dehiscence mechanism. Therefore it is called "functional male sterility".

The presence of viable pollens makes functional male sterility very attractive for hybrid breeding. The inbreeding of MS line or MS line propagation can be performed without any difficulties by compulsive-selfing of plants at anthesis. Using the functionally sterile parent as the seed line in the crossing block, the production of hybrid seeds can be ensured without manual operation.

Non-dehiscent anthers may be due to the absence of stomium [7,8,16]. Other possible

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explanations are that stomal cells may be tenacious and pressed by hooked petals which do not allow unfurling of corrolla [10], and anthers may be reflexed or hard and filaments are not able to elongate [12,14,20].

This paper reports the observations on morphological and histological features possibly related to anther indehiscence and also to its mechanism.

Materials and Methods

The materials used in this experiment were the cytoplasmic male sterile rices of TC 65 (P)MS or (Pai-co X TC 65/10), TNG 61 (P)MS or (Pai-co X TNG 61/10) which have the Pai-co cytoplasm, KR 7 MS or (*O. rufipogon* X KHS 1/9) which have *rufipogon* cytoplasm and their pollen parents. These plants were planted in a phytotron at two different day/night temperatures (25/20°, 30/25°C) and also under field conditions. For histological and scanning electron microscopic (SEM) observations, the spikelets of normal and CMS plants in the phytotron were collected at several stages from pre-anthesis to anther dehiscence.

Plastic, Paraffin Embeddings and Sectioning for Light Microscopy [1,2]

Freshly dissected samples were fixed in a mixture of 3% glutaraldehyde, 1% formalin and 0.1% Tween 20 prepared in a 0.05 M phosphate buffer (pH 7.2) for 4 hrs on ice and rinsed in three changes of cold buffer over a period of 2-3 hrs. Tissues were postfixed in 1% OsO_4 in 0.05 M phosphate buffer (pH 7.2) for 4 hrs on ice. Following washes with buffer, the tissue was dehydrated in a graduated series of alcohol and embedded in Spurr's medium ("Standard" formula) [21].

Semithin sections (0.7-1 μm)were cut on a MT 2 B ultramicrotome with glass knives. Plastic sections were floated on a drop of distilled water on slides coated with subbing solution (0.5% gelatin and 0.05% chrome alum). Slides with floated sections were heated at 60°C to dryness and stained according to one of the following schedules.

(a) Heamatoxylin-Safranin 0

The procedure of Warmke and Lee [25] was followed. All light microscopic figures except fig. 1a-b and 2e-f were prepared from sections stained by this routine.

(b) Periodic Acid-Schiff (PAS) procedure [5]

Slides were counterstained with methylene blue-Azure A [25]. Staining period of time was modified to 10 min. at 70°C. Starch localization was further confirmed with iodine-potassium iodide (I-KI) procedure.

For observations on the process of anthesis, mature anthers were fixed in Formalin-acetic alcohol, dehydrated in an ethyl-butyl alcohol series and embedded in paraffin in the usual manner. Sections were transversely cut at a thickness of 10-15 μ and stained with iron-heamatoxylin.

Scanning Electron Microscopy

Fixed anthers and spikelets were dehydrated in a graduated alcohol series followed by critical-point dry with liquid CO_2. The dried specimens were coated with gold. Surface details were observed with a Hitachi-SEM using accelerating voltage of 15 or 25 kv on the secondary electron emission mode.

Results

Histological-morphological observations on normal male fertile anthers of rice revealed that initially the anther wall was consisted of an epidermis, an endothecium,

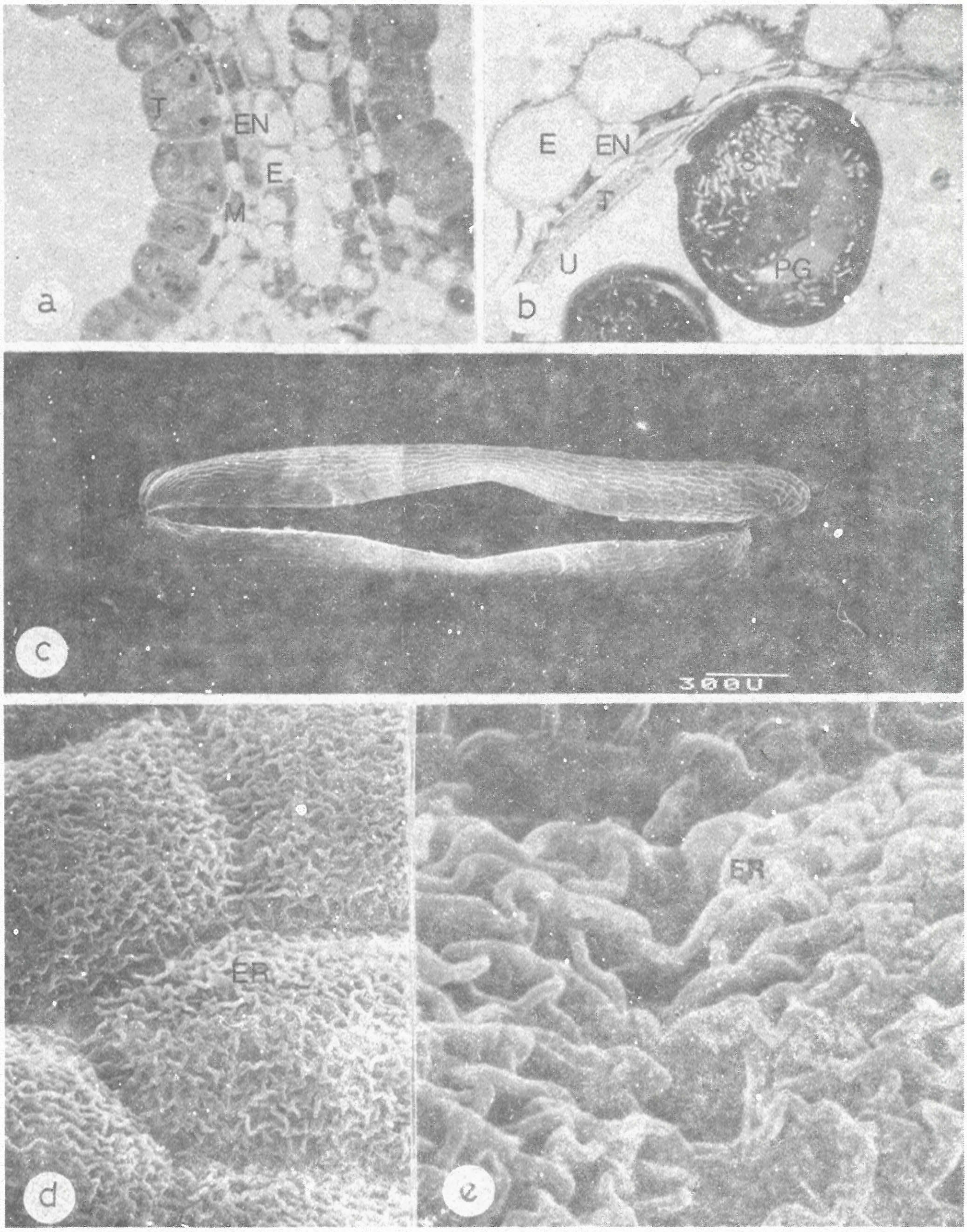

Fig. 1. a–e. LM (a–b) and SEM (c–e) views of normal anther development. a. At meiotic stage, the anther wall consists of epidermis (E), endothecium (EN), a middle layer cell (M), and tapetal cell (T), (600 X). b. At pollen ripening stage, tapetum has disintegrated, endothecium and middle layer are also degenerating. Pollen grain (PG) is filled with starch grains (S), (1,000 X). c. SEM view of whole mounts of dehiscent anther, (50X). d. Epidermal cell surface covered with ridges (ER), (1,500 X). e. Higher magnification of epidermal cells indicating the continuity of epidermal ridges between cells both in the long dimension and adjacent cells, (10,000 X).

one or more middle layers of cells and a singlelayered tapetum (Fig. 1 a). The middle layers degenerated quite early whereas tapetum and endothecium disintergrated later at pollen ripening stage (Fig. 1 b). At anthesis, the endothecium or subepidermal layers of cells is present only intermittently and shows a very feeble development of fibrous

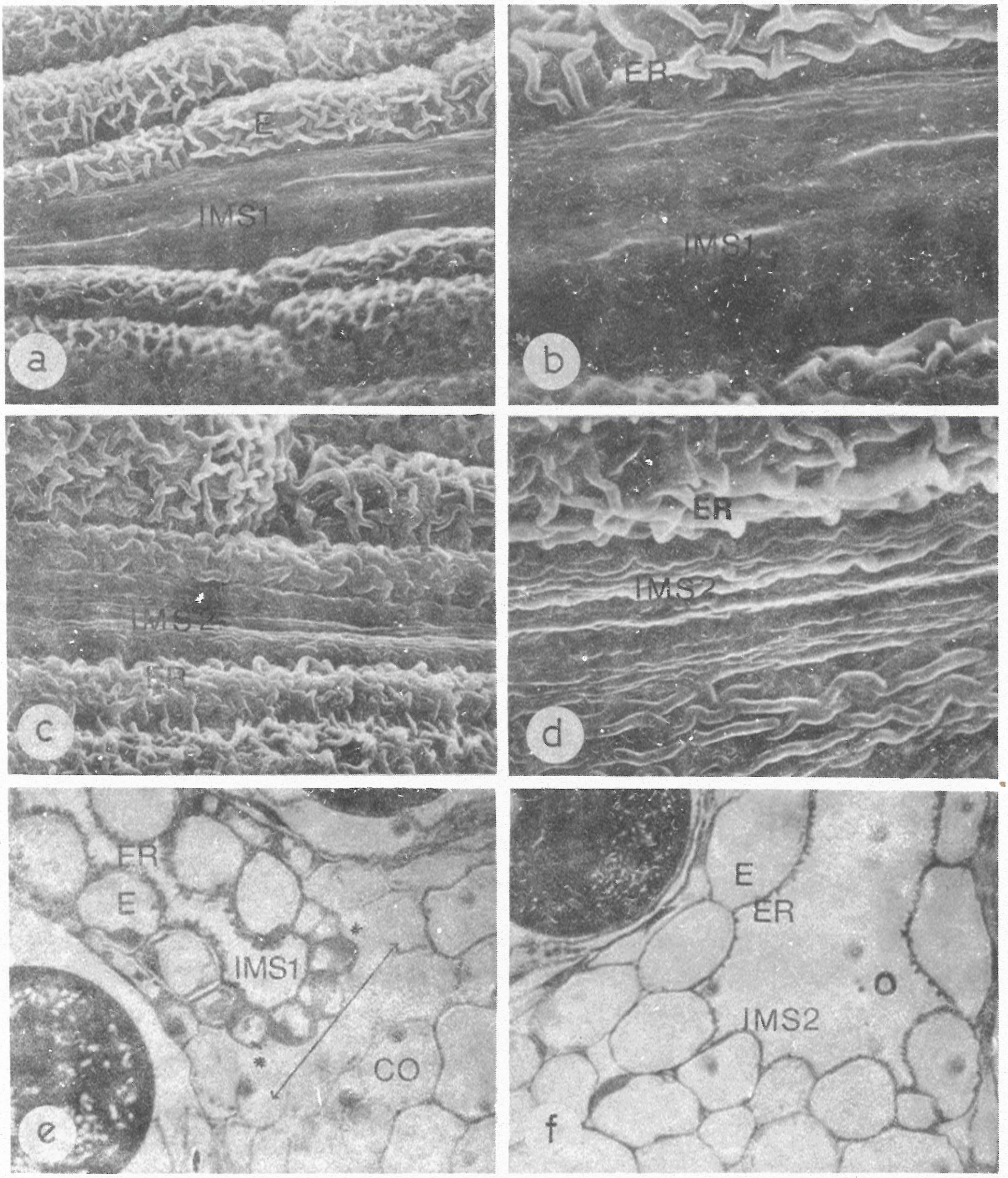

Fig. 2. a-f. SEM (a-d) and LM (e-f) views of intermicrosporangial stripe between microsporangia. a. Epidermal cells, along intermicrosporangial stripe 1 (IMS 1) which have no ridge and a few adjacent cells, (2,000 X). b. Higher magnification of IMS 1, (5,000 X). c. Epidermal cells along intermicrosporangial stripe 2 (IMS 2). Epidermal ridges on, IMS2 are straighter and parallel to each other, (3,000 X). d. Higher magnification of IMS 2, (5,000 X). e. Cross-section of IMS 1. The underlying parenchyma is indicated by a pair of arrows. Asterisk indicates the dehiscent site between IMS 1 and parenchyma cells, (1,000 X). f. The cross-section of IMS2, (1,000 X).

thickening on the cell walls. On the other hand, the epidermal cells have their inner and tangential walls slightly lignified and their outer walls cuticularized. The epidermis is thus the only layer enclosing the pollen grains when the anther mature. Surface view of whole anther at the onset of anthesis is shown in Fig. 1 c. Epidermal cells were covered with ridges which developed at the late young pollen stage and formed a highly ridged epidermal surface rapidly. Most epidermal ridges were crosswise and were oriented parallel to the long axis of the cells. They were not confined to a single cell but in most cases continued from cell to cell (Figs. 1 d-e). The cells of each anther wall layer possess

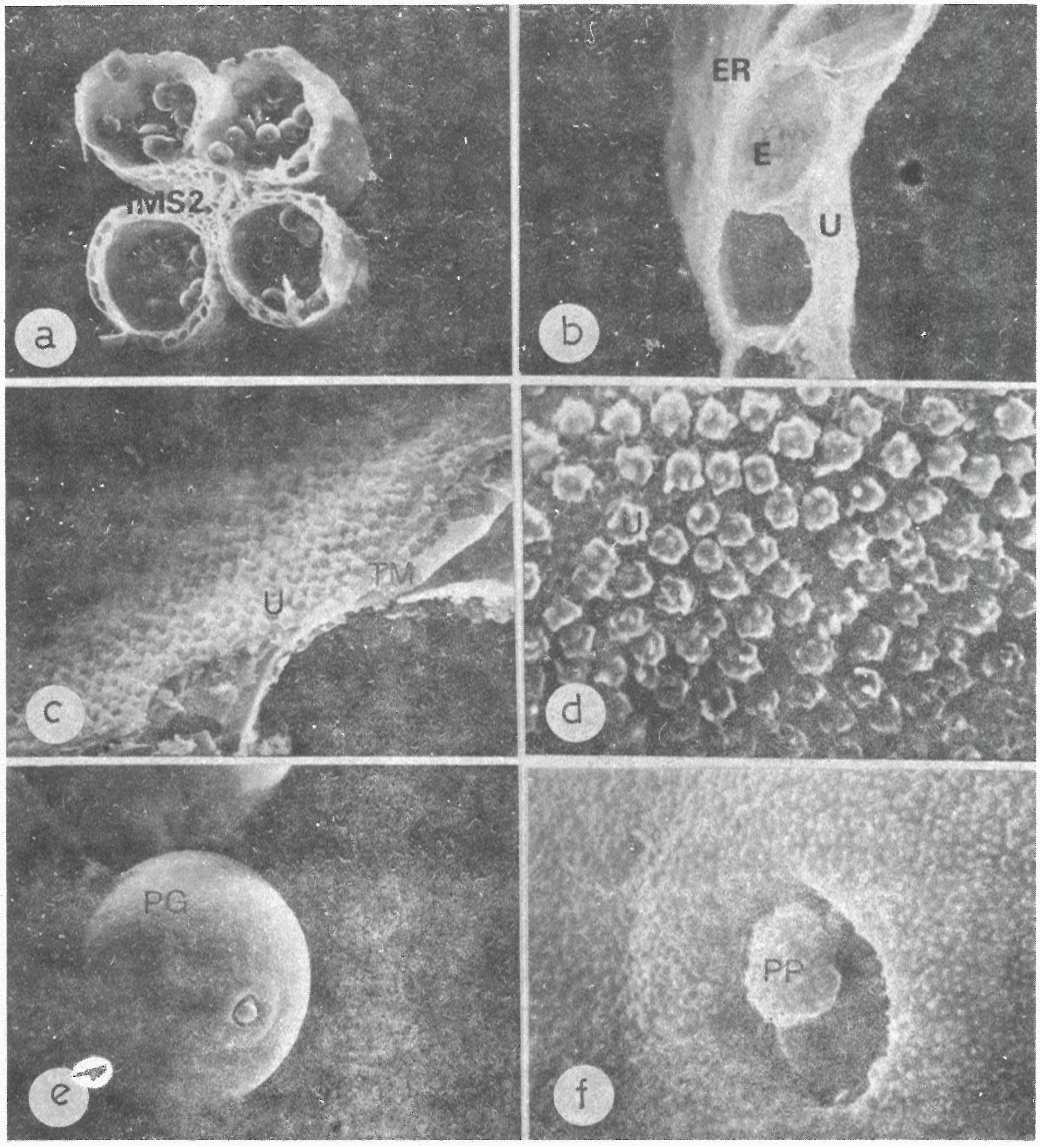

Fig. 3. a-f. SEM views of inner morphology in mature normal anthers. a. Cross-section of anther, (150X). b. Mature anther wall consists of epidermis, degenerated endothecium and tapetum with Ubisch bodies (U), (1,500 X). c. The inner surface of tapetum (TM) with U bodies, (5,000 X). d. Higher magnification of U bodies, (10,000 X). e. Mature pollen grain (PG), (1,500 X). f. The pollen grain surface and pollen pore (PP), (10,000 X).

their own particular orientation pattern. Epidermal cells are arranged parallel to the microsporangium circumference. The orientations of epidermal and endothecial cells are related to the mechanism of anther dehiscence (Figs. 1, a-c).

Another feature of the surface structure of mature anthers was the intermicrosporangial stripes existed between two microsporangia. Epidermal cells lacking ridges on the surface formed longitudinal stripes called intermicrosporangial stripe 1 (IMS 1)

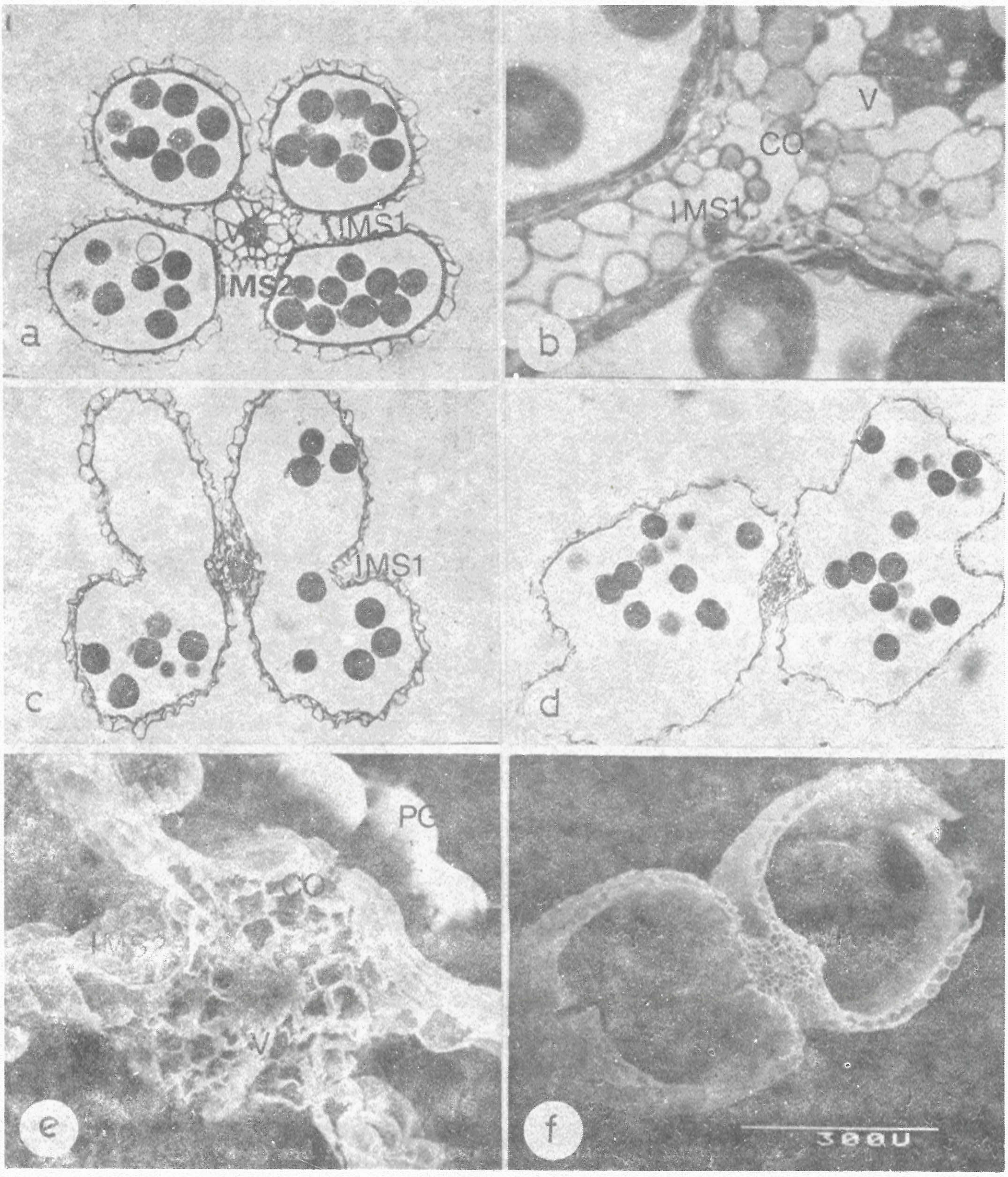

Fig. 4. a-f. LM (a-d) and SEM (e-f) views of anther dehiscent process. a. IMS1 was partially separated from connective tissue (CO) ; V, vascular bundle, (200X). b. Higher magnification of IMS1 separation from CO, (600X). c-d. Two microsporangial locules join into a single pollen cavity at pollen ripening stage, (200X). e. SEM view of two microsporangial locules joining into a single pollen cavity at pollen ripening stage, (500X). f. Anther dehiscence at anthesis, (150X).

where the locules fused through the separation of intervening connective cells (Figs. 2 a-b). These stripes were usually three to six cells wide. At anthesis, the mature anther dehisced from this pair of stripes (IMS 1). Another pair of stripes having ridges were called intermicrosporangial stripe 2 (IMS 2) (Figs. 2c-d) which were located along the connective cells and contained 10-20 cells, much wider than IMS 1. The ridges on IMS 2 were oriented parallel to each other and also to the long axis of the cell. The results of cross section observation (Figs. 2e-f) coincided with those of SEM observations regarding the presence of IMS 1 and IMS 2.

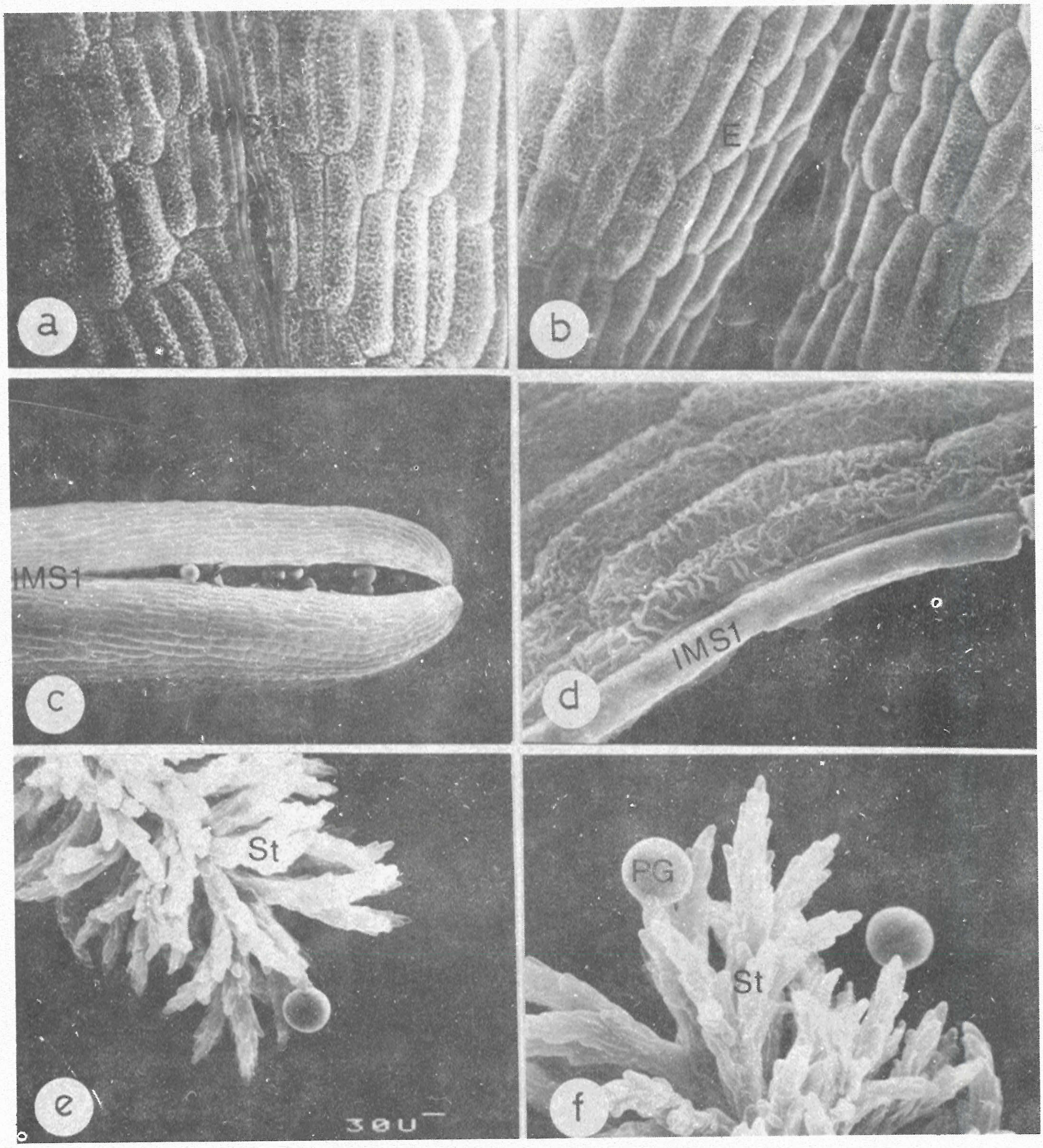

Fig. 5. a-f. SEM views of anther dehicence process. a. Anterior formation on IMS 1, (75 X). b-c. Anther dehisced along IMS 1, (75X, 50 X). d. Higher magnification of IMS 1 and a few epidermal cells after dehiscence, (1,000X). e-f. Pollen grains shed and adhered to stigma, (200X, 300X).

The inner and outer morphology of mature normal anther is shown in Fig. 3. It is consisted of an epidermis with ridges, a degenerated thin layer endothecium, Ubisch bodies on the surface of inner wall of tapetum and mature pollen grains (Figs. 3 a-b). The Ubisch bodies developed on tapetum cell wall after the tetrad stage and remained contact at anthesis (Figs. 3 c-d). The attachment of pollen grains to Ubisch bodies indicated that the spherical U bodies seemed to serve as channels of nutrient transport between tapetum and microspores. The surface of pollen grain also had similar structure to the Ubisch bodies (Figs. 2e-f). Pollen pore (Fig. 3 f) was conspicuous on the mature pollen grain and a pollen tube could emerge from this pore when pollen germination occured.

The process involved in the dehiscence of the normal male fertile anthers is shown in Fig. 4. Initially, there was a separation of lip cells (IMS 1) from the underlying parenchyma cells between the microsporangia along each side of the connective tissue (Figs. 4 a-b). This separation resulted in a join of two microsporangial locules into a

Table 1. Percentages of stainable pollens and seedset of functional male-sterile rices and their recurrent parents in different growth environments.

Entry	Treatment[a]	Pollen fertility Mean±SE (%)	Seedset Mean±SE (%)
TC 65	A	92.1 ± 0.8	96.3 ± 1.2
	B	86.0 ± 5.2	95.0 ± 2.1
	C	90.1 ± 1.2	92.3 ± 2.0
65 P 2	A	88.7 ± 4.4	1.1 ± 0.8
	B	12.2 ± 7.9	0.2 ± 0.4
	C	85.6 ± 3.8	1.5 ± 0.6
TNG 61	A	95.1 ± 2.0	95.6 ± 1.8
	B	79.3 ± 4.9	98.1 ± 1.2
	C	89.5 ± 4.8	93.2 ± 2.2
61 P 1	A	89.3 ± 5.2	1.5 ± 0.8
	B	27.5 ± 10.3	0.2 ± 0.2
	C	90.2 ± 5.6	1.8 ± 0.6
KHS 1	A	96.0 ± 2.0	95.4 ± 1.2
	B	93.4 ± 2.3	94.5 ± 1.0
	C	92.0 ± 3.0	92.6 ± 1.3
KR 7	A	88.8 ± 8.0	2.9 ± 2.1
	B	60.8 ± 8.9	0.6 ± 0.5
	C	78.5 ± 9.2	3.4 ± 2.6

[a] A : in the phytotron at 30/25° C.
B : in the phytotron at 25/20° C.
C : in the field condition.

single pollen cavity. Consequently four pollen sacs formed two pollen cavities (Figs. 4 c-f). The anthers of rice plant started to dehisce from the tip and base to the center, i. e. in a centripetal motion, along IMS 1 to form the anterior pore (Figs. 5 a-b). The separation of anterior epidermal cells from the underlying parenchyma cells along IMS 1, although initially for a short distance (Fig. 5 b), would proceed gradually to the full length (Fig. 1c and Fig. 5 c). After the opening of pelea and lemma, the anthers swang on the top of elongated filaments and the pollens shed on the stigma (Fig. 5, e-f).

The indehiscent character of functional male sterile anthers was first checked with a hand lens and was found to remain indehiscent until the anther dried up. When the anthers were smeared and treated with an 1% I-KI solution, 85% or more pollen grains were stainable although seedset percentage was consistently low under different weather conditions (Table 1). The compulsive self-pollination gave a seedset as high as 90% and their self-progenies were also anther indehiscence (funtional male sterility). The stainable pollen and seedset percentages are shown in Table 2.

Table 2. Percentages of stainable pollens and seedset of the progenies derived from compulsive self-pollination of functional male sterile rice.

Entry	Pollen fertility Mean±SE (%)	Seedset Mean±SE (%)
TC 65	93.6 ± 2.6	91.3 ± 1.2
65 P 2	86.4 ± 3.1	2.1 ± 1.6
65 P 2 S	88.2 ± 3.4	1.6 ± 0.9
TNG 61	91.8 ± 2.2	92.2 ± 2.0
61 P 1	85.4 ± 3.1	1.1 ± 0.8
61 P 1 S	86.4 ± 3.5	1.4 ± 0.8
KHS 1	90.4 ± 1.9	93.3 ± 2.8
KR 7	85.7 ± 3.4	2.1 ± 1.1
KR 7 S	86.2 ± 3.6	2.3 ± 1.4

Compared to normal anthers, the functonal male sterile anthers have well developed endothecial cells with strong fibrous thickenings at pollen ripening stage. These endothecial cells have their long axes arranged perpendicularly to the microsporangium circumference (Figs. 6 a-b). The epidermal cells were also slightly thick-walled. Another difference was that the surface structure of epidermal cells at IMS 1 seemed to be lignified and cuticularized. As mentioned before, the surface of epidermal cells that form longitudinal stripes between the microsporangia in the dehiscent anther were lacking of ridges, but ridges or spurs were found on the indehiscent anthers (Figs. 6cd). In addition, the ridges frequently showed more straight figures and were parallel more closely to each other. Therefore, the separation of IMS 1 from the underlying parenchyma between the microsporangia or separation from each other along the IMS 1 did not occur as it did in the dehiscent type, and the anther possessed two or four locules

after anthesis. As the anther wall of the individual lobe was quite strong, it did not rupture and thus the anthers remained indehiscent and pollination could not take place (Fig. 6 e–f). At anthesis, the filaments could elongate as usual in this type of male sterility, and the anthers remained outside of the spikelet after flowering.

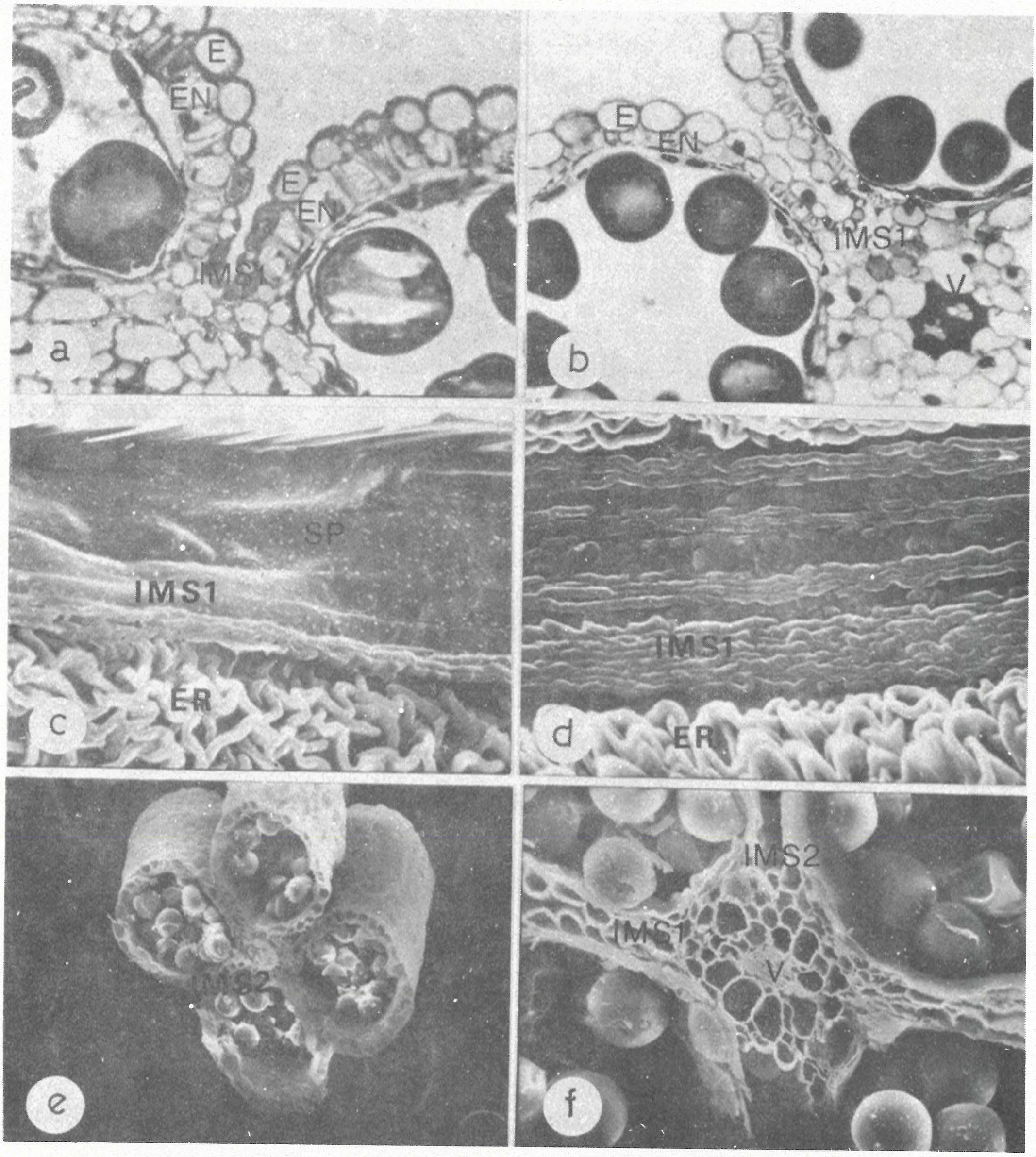

Fig. 6. a–f. Effect of cytoplasm on the development of dehiscent site. a–b. Cross-sections of indehiscent anther at pollen ripening stage. The endothecium layer is well developed and slightly thickening, and their long axes are perpendicular to the microsporangium circumference. The IMS 1 is slightly lignified, thus no separation occur between IMS 1 and CO, (400 X). c–d. SEM views of IMS 1 surface on indehiscent anther, noting spurs (SP) and ridges, (5,000X). e–f. The indehiscent anther at anthesis. Dehiscent site is not formed. The pollens in pollen sacs were not shed, (150 X, 500X).

Discussion

The mechanism of anther dehiscence or opening of microstrobili and the release of pollen vary according to different plant families. The stamens of the vast majority of the appoximately 225,000 species are dehiscent. Their anthers release pollen grains by valves, by terminal pores or, typically by lateral longitudinal (rarly transverse) slits [13,19]. Forrice plante, the anther starts dehiscing from the tip and the base toward the center after opening of pelea and lemma, then proceeding gradually to the full length. It is a longitudinal dehiscence or a slit-like opening, the most common form in angiosperms.

The dehiscence of anther is a desiccatory process. The process has been characterized as being affected by a hygroscopic and/or a cohesion mechanism. Hygroscopic (imbibition) mechanisms depend entirely upon volumetric changes in cell walls, whereas cohesion mechanisms involve volumetric changes in cell lumina, the cell walls undergoing largely passive deformation. Many workers now accept a cohision mechanism for anther dehiscence [15,19,22,24]. Some features of the stamen such as open stomata, a weakly developed cuticule, a prominent intercellular-space system and xylem lacunae may play a role in anther dehiscence, since such features would tend to promote a rapid loss of water or a disruption of the water supply to the anther [19]. We also suggest that some additional force and ridged epidermal layer would be necessary to accomplish the separation of IMS 1 from the underlying parenchyma. The formation of anterior pore may be the result of deformation of the endothecial wall thickening.

The change of atomospheric humidity is the most frequent causative agent leading to anther wall rupture. Temperatures also affect dehiscent characteristics [17,18,23]. In the phytotron and field experiments, we obtained that there were no significant difference in seedset percentage of functional male sterile plants. Therefore, this type of male sterility is stable under such environmental conditions. It is also showed that these weather conditions did not affect anther indehiscence.

One of the most significant aspects of indehiscent anthers of functional male sterile plants is that the separation of IMS 1 from the underlying parenchyma does not occur. This may be due to the well developed endothecium and their particular orientation pattern. Another difference from those of mormal fertile plant was the spurs or ridges on the surfce of IMS 1 of epidermal cells. Those ridges may be the products of epidermal cell wall and their outer walls are cuticularized. It may be suggested that the constructive force on such IMS 1 may tend to prevent separation from each other along the IMS 1. Therefore, well developed endothecium and spurs or ridges at IMS 1 may prevent the anthers to form anterior pore and pollen shedding.

A number of male sterility genes are known to prevent pollen release by modifying normal differentiation or functioning of the stomium and thus prevent release of fertile pollen through failure of anther dehiscence. These functional male sterile types leave the option of forced pollen release open. They are found not only as recessive traits in tomato [4] but also as dominant traits in potato [6]. A genetic nondehiscent anther cha-

racter in sorghum[26] and a similar situation in cotton[11] have been reported. In this paper, the anther indehiscence was transimitted from generation to generation through egg cytoplasm rather than nuclear genes.

Kitamura[9] found that all F_1's of Japanese varieties X "Ta-strain" were normal in both seed-setting and pollen fertililes, whereas F_1's of the reciprocal crosses showed a wide range of seedset percentages in spite of their good pollen fertility. The sterility was connected with the difficulty in anther dehiscence caused by Tadukan cytoplasm. Yabuno[27] reported that the *glaberrima* strain of substitution lines having the cytoplasm of japonica variety Akebono was associated with cytoplasmic male sterility and anther indehiscence. The pollen fertility restoring gene Rf_i also functioned in homozygous condition as a restorer of anther dehiscence.

Since the selfing progenies of indehiscent anther plants were also anther indehiscent and pollens of these plants were full fertile, it may be suggested that this type of male sterility can be maintained by hand pollination or compulsive-selfing. To search for stable fertility restoring (gametoficant) chemical will be helpful. If gametoficants were available, there would be no need to develop R-lines. Unstable genetic restoration of fertility would be trouble some to hybrid variety breeders. A systemic chemical of this kind would be ideal. Therefore, from the agronomic point of view, functional male sterile lines are very attractive for hybrid breeding. Unfortunately this attractive sterility occurs only in a limited number of crops. The crop which has been mostly investigated so far is tomato [10]. It is also found in eggplant, cabbage and *Streptocarpus*[8]. The use of functional male sterility in tomato is limited by two factors. One is that the indehiscence is sensitive to environment. Depending on weather condition up to 50% self-fertilization may occur in the seed lines. The second factor is that the stigmas of tomato are hidden within a cone of connate stamen. Hence cross pollination is severely impeded. This problem can be bypassed, however, by the use of mutants having exserted stigmas.

In the functional male sterility of rice, several problems in hybrid breeding need to be solved. The presence of widespread hybrid sterility in rice species is disadvantageous for hybrid-variety breeding. We need more information regarding the effect of genetic and environmental interaction on male sterility and fertility restoration. Perhaps the most importatn problem is how to modify the floral structure of male sterile rice to increase its outcrossing potential.

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Literature cited

1. Cheng, P. C. 1978. Techniques on plastic sectioning and staining. Sci. Technol. (Taipei). 2 (4) : 85-104. (in Chinese).
2. Cheng, P. C., R. I. Greyson and D. B. Walden. 1979. Comparison of anther development in genic male sterile (ms 10) and in male fertile corn (*Zea mays*) from light microscopy and

scanning electron microscopy. Can. J. Bot. 57 (6) : 578-596.

3. Cheng, Y. K. and C. S. Huang. 1979. Studies on cytoplasmic-genetic male sterility in cultivated rice (*Oryza sativa* L.). I. Effect of different cytoplasm sources on male abnormalities at anthesis. J. Agr. Assoc. China. NS. 106 : 1-22.
4. Clayberg, C. D., L. Butler, E. A. Kerr, C. M. Rick and R. W. Robinson. 1966. Third list of known genes in the tomato. J. Heredity 57 : 189-196.
5. Feder, N. and T. P. O'Brien. 1968. Plant microtechinque : some principles and new methods. Am. J. Bot. 55 : 133-142.
6. Grun, P. 1970. Changes of cytoplasmic factors during the evolution of the cultivated potato. Evolution 24 : 188-198.
7. Hoff, B. J. and D. Chandrapny. 1973. Inheritance of two male sterile characters in rice. Agro, Abstr. 65th Ann. Meet. Am. Soc. Agron. p. 7.
8. Jasmin, J. J. 1954. Male sterility in *Solanum melongena* : Preliminary report on a functional type of male sterility in eggplant. Proc. Am. Soc. Hort. Sci. 63 : 443.
9. Kitamura, E. 1962. Studies on cytoplasmic sterility of hyhrids in distantly related varieties of rice, *Oryza sativa* L. I. Fertility of F_1 hybrids between strains derived from a certain Philippine X Japanese variety crosses and Japanese varieties. Jap. J. Breed. 12 : 81-84.
10. Larson, R. E. and S. Paur. 1948. The description and inheritance of functionally sterile flower mutant in tomato and its probable value in hybrid tomato seed production. Proc. Am. Soc. Hort. Sci. 52 : 355-364.
11. Murthi, A. N. and J. B. Weaver, Jr. 1974. Histological studies on five male sterile strains of upland cotton. Crop Sci. 14 : 658-663.
12. Olmo, H. P. 1943. Pollination in Almeriar grape. Proc. Am. Soc. Hort. Sci. 42 : 401-406.
13. Puri, V. 1970. Anther sacs and pollen grains : some aspects of their structure and function, J. Palynology 6 : 1-17.
14. Ramaer, H. 1935. Cytology of *Hevea*. Genetica 17 : 193-236.
15. Richter, S. 1929. Über den Öffnungsmechanismus der antheren bei einigen Vertreter der Angiospermen. Planta 8 : 154-84.
16. Roath, W. W. and E. A. Hockett. 1971. Genetic male sterility in barley. III. Pollen and anther characteristics. Crop Sci. 11 : 200-203.
17. Satake, T. 1978. Hight temperaure-induced sterility in indica rice at flowering. Jap. J. Crop Sci. 47 (1) : 6-17.
18. Sawada, S. 1974. Anther indehiscence in rice plants as a cause of sterility when induced by low temperatures. Res. Bull. Obihiro Univ. 8 : 629-636.
19. Schmid, R. 1976. Filament histology and anther dehiscence. Bot. J. Linn. Soc. 73 : 303-315.
20. Sprangue, G. F. 1939. Heritable characters in maize : Vestigal glum. J. Heredity 30 : 143-145.
21. Spurr, A. R. 1969. A low viscosity epoxy resin embedding medium for electron microscopy. J. Ultrastruct. Res. 26 : 31-43.
22. Straka, H. 1962. Nicht durch Reize aüsgeloste Bewegungers. In W. Ruhland (Ed). Handbuch der Pflanzenphysiologie. 17 (2) : 716-835. Berlin : Springer-Uerlag.
23. Suzuki, S. 1978. Anther and pollen abnormalities induced by cold treatment and their varietal difference in rice plant. Jap. J. Breed. 28 (1) : 21-32.
24. Von Guttenberg, H. 1971. Bewegungsgewbe und perzeptionsorgane, In K. Linsbauer's Handbuch der Pflanzenanatomie, 2nd ed., 5 (5). Berlin : Gebrüder Borntraeger.
25. Warmke, H. E. and S. L. J. Lee. 1976. Improved staining procedures for semithin epoxy sections

of plant tissues. Stain Technol. 51 : 179-185.

26. Werbster, O. J. and S. P. Singh. 1964. Breeding behavior and histological structure of a nondehiscent anther character in *Sorghum vulgare* Pers. Crop Sci. 4 : 656-658.

27. Yabuno, T. 1977. Genetic studies on the interspecific cytoplasm susbtitution lines of Japonica varieties of *Oryza sativa* L. and *O. glaberrima* Steud. Euphytica 26 : 451-463.

水稻細胞質—遺傳因子雄不稔性之研究[1]

Ⅱ、構造雄不稔花藥之形態及組織學的研究

成 游 貴[2] 黃 眞 生[3]

摘 要

具有白殼細胞質之「臺中 65 (白殼) MS」與「臺農 61 (白殼) MS」以及具有 *O. rufipogon* 細胞質之「高雄選 1 (R) MS」等細胞質雄不稔系統，其不稔之主要原因爲花藥不能裂開，但花粉發育卻皆正常，此型雄不稔稱之爲構造性雄不稔性。利用掃描電子顯微鏡與光學顯微鏡觀察構造性雄不稔花藥與正常花藥之結果得知，不裂開花藥與正常花藥間最顯著之差異爲內皮細胞之强韌纖維化與其長軸方向的組成及輕微角質化之表皮細胞，因此開花時花粉囊間帶 I (IMS 1) 與藥隔薄壁組織間不發生分離。另外在不裂開花藥之 IMS 1 表面上發現有部分刺狀物或表皮脊狀凸起，與正常花藥 IMS 1 表面光滑不同。因此開花後構造性雄不稔之花藥經常維持着四個或兩個花粉囊，故花藥之藥壁結構及黏接 (Cohesion) 機制之物理過程與花藥裂開似有密切關係。

在水稻，此種構造性雄不稔性，可以用强迫自交或其他方法來繁殖後代而不須要代代回交其輪迴親，因此在發展雜種水稻上，此種雄不稔性具有很大的功用。

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Carbohydrate, N, P and K status of developing rice (*Oryza sativa* L.) plants grown in the first and second crop seasons in Taiwan[1]

C. S. Chen, D. D. Huang, M. C. Shen and D. J. Liu [2,3]

Abstract : Concentrations of total nonstructural carbohydrates, N, P and K in different plant parts of rice were analyzed at stages of plant development. Differences between crop seasons were also studied to investigate the physiological causes of low yield of the second crop rice.

Accumulation of total nonstructural carbohydrates (TNC) in culms and leaf sheaths was most evident during the period of panicle development. Highest TNC concentration was recorded earlier in the second crop (25 days before heading) than in the first crop (18 days before heading) for rices grown in Taichung. It occurred at heading stage in both crops in Taipei area. The first crop rice accumulated significantly higher amount of TNC in culms at panicle emergence than the second crop rice.

Concentration of N was higher in leaf blades whereas those of P and K were higher in culms and leaf sheaths. Nitrogen concentration in plant tissues was higher in the first crop during the vegetative growth stage but the difference between crops was less significant as rices grew toward heading. Leaf blades of the second crop rice were considerably lower in K concentration than those of the first crop rice throughout the whole developmental period.

Less TNC stored in culms and leaf sheaths before heading, lower K concentration in leaf blades, and the composition, rather than concentration, of N were suggested as possible physiological causes affecting yield potential of the second crop rice in Taiwan.

Carbohydrates in the form of sugars, starch and other polysaccharides usually reach a maximum concentration in the leaf sheaths and culms of rice plants before the emergence of panicles. The stored carbohydrates could be either retranslocated to the panicles or consumed by respiration during the following grain-filling period. The importance of such carbohydrates in relation to grain yield of many cereal crops has long been a subject of interest as reported by many researchers [2,7,15,16,20,21,26] Although

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Lian and Tanaka [7] suggested that in rice, carbon assimilated before flowering was used for grain filling with relatively low efficiency, Yoshida and Ahn [26] assessed the contribution could be as high as 38% of total grain yield. By using ^{14}C, Cock and Yoshida [2] further acknowledged that with a translocation efficiency of 68 to 77 %, the contribution of stored carbohydrates to grain carbohydrates was 24 to 27%, which was equivalent to 1.9 to 2.1 t/ha of rough rice at 14% moisture.

Environmental conditions were usually considered important in influencing rice physiology and causing the low yield of the second crop rice in Taiwan. By statistical analysis of changes in dry weight, Wu *et al.* [24] estimated that preheading storage in the vegetative parts accounted for 14 and 21% of total grain yield for the first and second rice crops, respectively. However, differences in carbohydrate metabolism between the two crops has not been verified so far. A series of experiments were conducted in this laboratory to investigate the carbohydrate status and its impact on the development and yield performances of rice plants. We reported here the changes in concentrations of total nonstructural carbohydrates, nitrogen, potassium and phosphorus in different plant fractions from transplanting to heading. The results on redistribution of stored carbohydrates to panicles and the influences of environmental factors and cultural practices will be published elsewhere.

Materials and Methods

Japonica rice Tainung No. 61 and long-grain indica rice Chianung sen No. 11 were transplanted and grown in the experimental farm of Taiwan Agricultural Research Institute at Taipei, Taiwan in the second crop season of 1976 and the first crop season of 1977. After the Institute had moved to Taichung, japonica rices Tainan No. 5 and Tainung No. 67, and indica rices Taichung sen No. 5 and Taichung Native No. 1 were grown in the first and second crop seasons of 1978. All the experiments were set in 5 × 9.5m plots with six replications in a randomized complete block design. Planting density was 22.5×22.5 cm. A soil test held in Taichung (1978) just before transplanting of the second crop rice indicated 1.09 % organic matter, 12.5 ppm available P, 24.0 ppm available K, and 10.6 meq/100g soil of CEC; pH was 6.60. Before transplanting, N, P and K were applied to the paddy field at, respectively, 40, 60 and 45 kg/ha in the first and 35, 60 and 50 kg/ha in the second rice crop. Additional nitrogen at a rate of 30 kg/ha each was topdressed twice in both crops.

At intervals between transplanting and heading, the above-ground portion of 6 to 8 rice plants was harvested from each replication. After cleaning with tap and distilled water, one set of plants was then divided into leaf blade (referred to hereinafter as leaf) and culms plus leaf sheaths (culm). Samples were dried in an air-drafted oven at 100°C for 1 to 1.5 hrs followed by 70°C until dryness (4 to 5 hrs or longer if necessary). This method of drying was reported by Raguse and Smith [18] as capable of giving values of total nonstructural carbohydrates (TNC) approximately most closely to those from freeze-dried tissue. After dry weight had been determined, the samples were ground with a Wiley mill through a 40-mesh screen. Concentration of total nonstructural

carbohydrates were then determined according to Smith[19]. Ground samples were first hydrolyzed with takadiastase ("Clarase 900" or "Clarase 40,000", obtained from Miles Laboratories Inc., U. S. A.) at 40°C for 44 hrs, and reducing sugars were measured by the Shaeffer-Somogyi copperiodometric titration method described by Heinze and Murneek (cf. [19]).

Samples obtained from 1978 experiments were also analyzed for some major elements. Nitrogen was determined by semi-micro Kjeldahl procedures. For K and P analyses, a 0.5000 g of dried ground tissue was weighed into a 50-ml Vycor crucible. Duplicate weights of each sample were placed into a cool muffle furnace and muffled at 550°C for 5 to 6 hrs[5]. After ashing, the residue was taken up in 5 ml of HCl (1+3), transferred to 50-ml volumetric flask by filtering through Whatman No. 2 filter paper, and diluted to the mark with hot, double distilled water. Potassium was determined by using a Corning Model 400 flame photometer. Phosphorus was determined by the colorimetric-(Mo) blue method[1] and was read at 650 nm with a Perkin-Elmer Model 55 UV-VIS spectrophotometer.

Results

For the four rice varieties grown in 1978, leaf dry weight increased gradually but steadily up to 72 days after transplanting (DAT) in the first crop and to 60 DAT in the second crop (data not shown). It then decreased slightly toward heading. Maximum rate of increasing leaf dry weight occured between 50 to 72 DAT in the first crop and between 26 to 51 DAT in the second crop season. The second crop rice was more leafy and thus had higher leaf dry weight than the first crop rice at the time of panicle emergence. However, an accelerated leaf senescence was observed in the field during the grain-filling period of the second crop rice . As for the dry weight of culms, maximum rate of increase started 50 and 40 days after transplanting for the first and second crops, respectively, and continued until heading stage. Average culm dry weight of the four varieties was slightly higher for the first crop rice. No significant difference in total dry weight was found between crops. Comparison among varieties showed that Taichung sen No. 5 had the highest total dry weight followed by Tainung No. 67, Taichung Native No. 1 and Tainan No. 5 in that order in both crop seasons.

Concentrations of total nonstructural carbohydrates (TNC) were higher in culms than in leaf blades regardless of variety, location or crop season considered (Figs. 1 and 2). For experiment held in 1976-1977 at Taipei, it was noted that TNC concentration of rice seedlings was higher in the first than in the second crop, presumably due to lower temperature during the nursery period. Fig. 1 showed that TNC concentration in leaf blades of Tainung No. 61 rice grown in the first crop season decreased sharply in the early vegetative growth stage, reached a minimum between 40 to 70 days after transplanting, and increased gradually toward heading. It was higher for the first (8.6 %) than for the second (6.2%) crop rice at the time of panicle emergence. A similar trend was also recorded in leaf blades of Chianung sen No. 11 rice with the exceptions that in the first crop TNC concentration decreased from 70 to 90 days after transplant-

ing and was lower than that of the second crop rice at comparable developmental stages (Fig. 1). Generally, leaf blades of rice plant possessed TNC concentrations fluctuated within a narrow range, i.e., 4 to 8% throughout the tested period of this experiment.

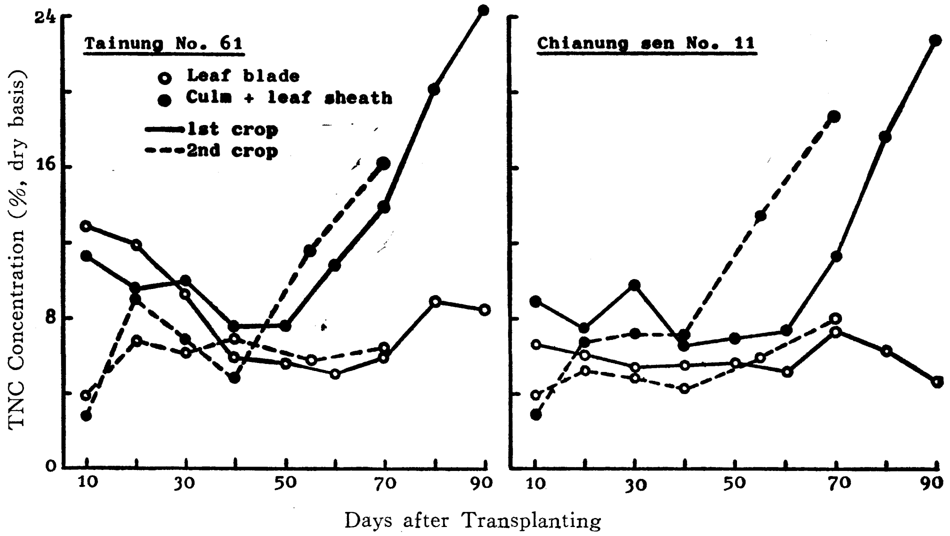

Fig. 1. TNC concentrations in plant fractions of developing rices grown in the first and second crop seasons in Taipei (1976-1977)

Fig. 1 also showed the carbohydrate status in rice culms from transplanting to heading in the two crop seasons of 1976-1977. For Tainung No. 61 variety grown in the first crop, TNC concentration decreased during the first 40 days and increased drastically starting from 50 days after transplanting (about 1 week before maximum tillering stage) to heading. It increased from 7.6 to 24.7% during this period. Accumulation of carbohydrates in culms of the second crop rice was also most evident in the 30 days prior to heading during which the panicles developed. However, the highest value (16.3%) recorded at heading was 8.4% lower than that of the first crop rice. Developing Chianung sen No. 11 rice showed an almost identical pattern of changes in carbohydrate status (Fig. 1). TNC concentration peaked at heading stage in both crops. At this developmental stage, culms contained 22.6% of total dry weight as available carbohydrates in the first crop and the value was only 18.5% in the second crop.

Results of carbohydrate analysis of rices grown in 1978 at Taichung area were shown in Fig. 2. In the first rice crop, TNC concentrations in leaf blades were low at active tillering stage (about 35 days after transplanting) and reached the highest level (8 to 9%) when the plants were gaining maximum number of tillers. It then declined steadily throughout the sampling period. In the second crop season, concentrations changed little until 51 days after transplanting. The decline thereafter was followed by an increase starting from booting toward heading stage. No significant difference in concentration or pattern of changes of leaf TNC was observed among the four varieties tested.

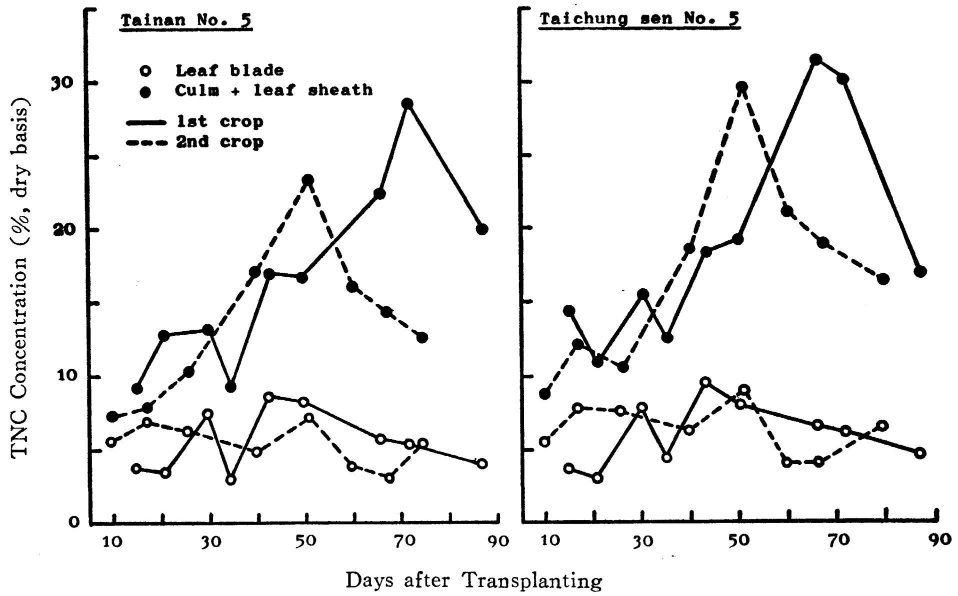

Fig. 2. TNC concentrations in plant fractions of developing rices grown in the first and second crop seasons in Taichung (1978)

Generally, total nonstructural carbohydrates accumulated continuously in the culms and leaf sheaths after transplanting and peaked around spikelet-formation stage in the 1978 experiments. Concentrations were then decreased with the advance of maturity (Fig. 2). A comparison between the two crop seasons in Taichung showed that culms of the second crop rice gained maximum level of TNC earlier than that of the first crop rice. Highest TNC concentrations were reached at 18 and 25 days before heading for the first and second crops, respectively, in this experiment. At comparable developmental stages , culms of rice plant had higher TNC percentages in the first than in the second crop season. This was especially true for the two japonica varieties at 18 days before heading where a difference up to 9% of total dry weight (29.4% vs. 20.2%) was observed in Tainung No. 67 rice. The difference in peak concentration between crops was less significant for indica varieties Taichung sen No. 5 and Taichung Native No. 1. With the only exception of Taichung sen No. 5, the other three varieties stored far more carbon energy in culms at heading in the first crop (averaged at 22.4%) than in the second crop season (11.9%).

Fig. 3 showed nitrogen concentrations in leaf and culm fractions of Tainan No. 5 and Taichung sen No. 5 rice varieties at various developmental stages. In contrast with total nonstructural carbohydrates, concentration of N was higher in leaves than in culms and a steady and marked decline was found in either fraction from initial tillering to panicle-formation stage (21 to 72 and 15 to 51 days after transplanting for the first and second crops, respectively). It increased slightly in both the leaves and culms during the last two to three weeks before heading. No varietal differences were observed

in terms of either N concentration or pattern of changes throughout the whole sampling period. However, N concentrations in tissues of rice plant grown in the first crop was higher during the first 50 to 60 days after transplanting and was lower thereafter until heading when compared with those at comparable stages in the second crop, indicating the existence of seasonal differences in the metabolism and accumulation of nitrogen in developing rice plant.

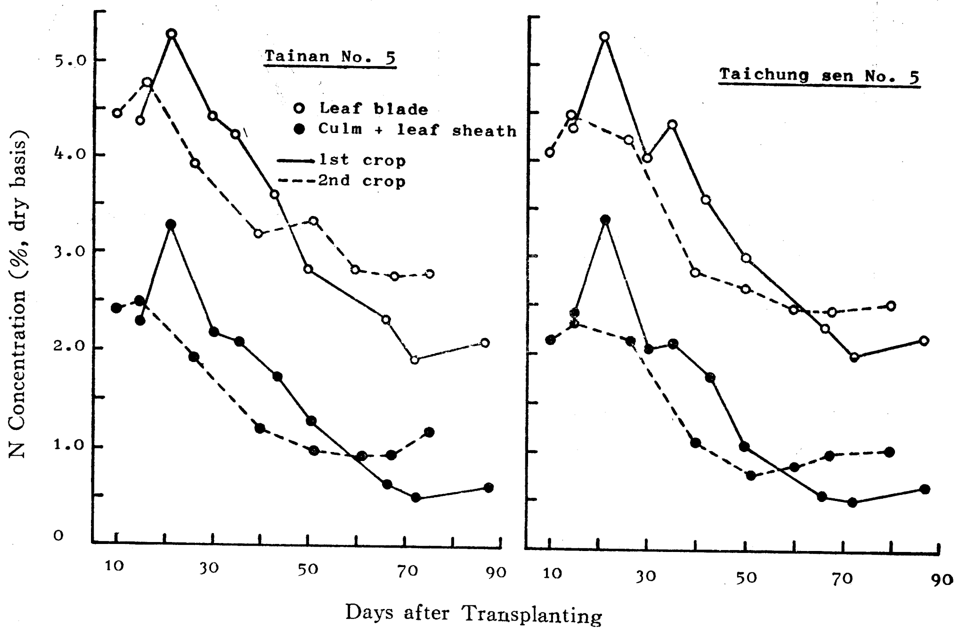

Fig. 3. Nitrogen conceentrations in plant fractions of developing rices grown in the first and second crop seasons in Taichung

Phosphorus concentrations of plant fractions compared between crops and among developmental stages were shown in Fig. 4. Phosphorus accumulation was more prominent in culms than in leaves for both rice crops. It is generally true that the first crop rice had higher P concentrations than the second crop rice except in early developmental period. Phosphorus concentrations of rice tissues also showed the tendency of declining with advancing maturity and reached minimum level around panicle formation stage. Sharp increase of P concentration in leaves and culms was a common characteristic in both the first and second rice crops. Comparison among varieties showed that indica rices had a higher P concentration at heading stage than japonica varieties.

Fig. 4 showed the status of potassium in plant fractions of developing rices. It was evident that K concentrations were higher in culms than in leaf blades during the whole period from transplanting to heading in either crop season. Declining K concentration in culms were found beyond 35 to 43 days after transplanting in the first crop rice. On the other hand, there was a gradual build-up of K concentration in leaf blades during the first 35 days of growth and the following decline was much slower than that in culms. Similar trends were also found when rice was grown in the second crop season.

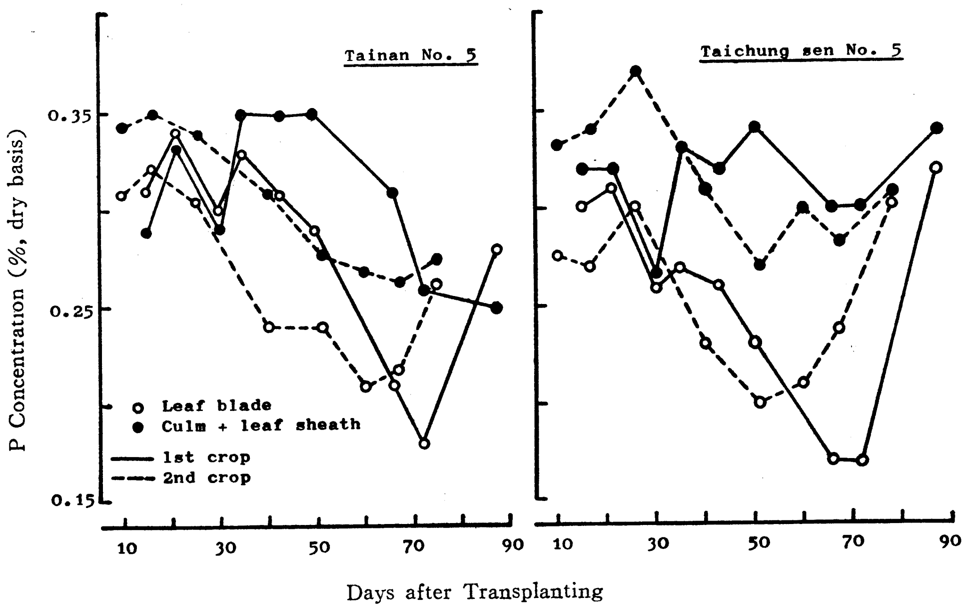

Fig. 4. Phosphorus concentrations in plant fsactions of developing rices grown in the first and second crop seasons in Taichung

Comparison between the two crops showed that in either the leaf blade or the culm, K concentrations were always higher in the first than in the second crop rice. When results were considered together with the changing pattern of dry weight with advancing maturity, it was probable that K was exported from leaf blades to panicles via culms in the later developmental period of rice plant.

Discussion

For 1978 experiments held in Taichung, the accumulation of dry matter at heading stage was similar between the two crops. However, rices grown in the second crop had a heavier leaf dry weight and a lighter culm dry weight than those grown in the first crop season, indicating less pre-stored energy source in stems and leaf sheaths at this stage. High temperature during the early growth phase of the second crop rice tended to cause vigorous vegetative growth. Lian *et al.* [8] reported that dry weight of total plant at flowering was slightly higher for the second crop rice but showed no difference at harvest. In most cases, excessive early vegetative growth is not desirable since it tends to depress grain yield of rice [4].

In Taipei area, culms of the first crop rice had higher TNC concentrations than those of the second crop rice and maximum levels of TNC were obtained just before heading in both crop seasons (Fig. 1). Similar results were also found in Taichung experiments but the highest concentrations were recorded much earlier, i. e., 18 days before heading for the first crop rice and 25 days before heading for the second (Fig. 2). In the southern part of Taiwan (Pingtung), Lian and Chen [9] found that total

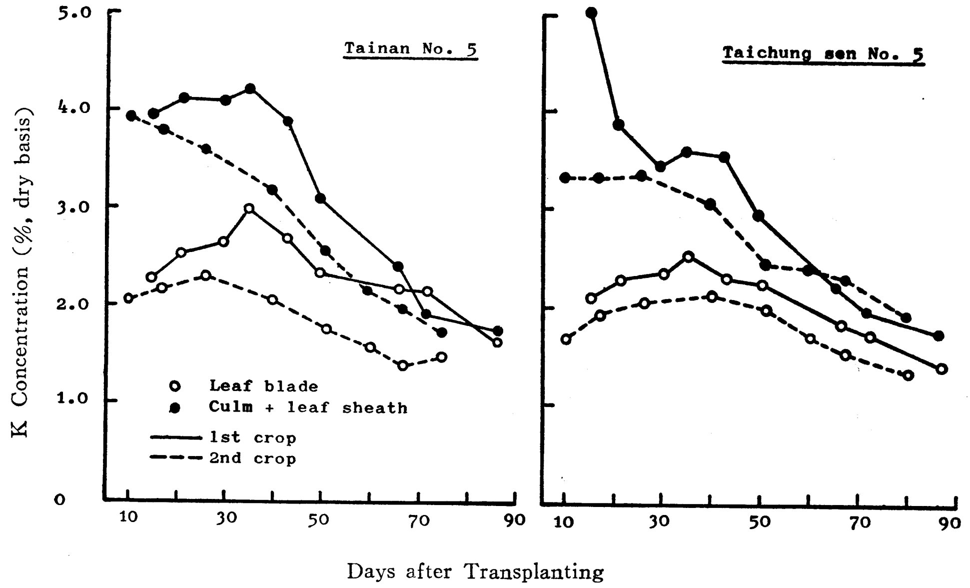

Fig. 5. Potassium concentrations in plant fractions of developing rices grown in the first and second crop seasons in Taichung

carbohydrates in straws peaked at heading stage for IR-8 and Chianan No. 8 rices. Tai[22] and Lin and Tai[12] also pointed out the stages between booting and heading as the occurrence of maximum total carbohydrate concentrations in four rice varieties. The fact that indica rices had more TNC accumulated in culms than japonica varieties in the second crop (Figs . 1 and 2) might indicate varietal difference in adaptation to specific environmental conditions.

Leaf blades contained little starch and their carbohydrate storage was minor as compared with that in culms and sheaths[17]. As shown in Fig. 2, TNC concentrations of leaf blades kept decreasing from 43 days after transplanting in the first crop. However, there was an increase starting from 60 days after transplanting in the second crop season. This, together with the decreasing TNC levels in culms, might suggest an accumulation of carbohydrates in leaf blades and a subsequent retardation of leaf photosynthetic activity. Lin and Su[11] found that both activity and efficiency of photosynthesis were lower in the second crop. The relationship between photosynthesis and carbon deposition into culms and panicles in the two crops should be further studied when low yield of the second crop rice is concerned.

Carbohydrates stored in culms before heading could be translocated to grains and thus contribute to grain yield[25]. Results of this experiment showed that TNC concentration at heading was much higher in the first than in the second rice crop. Liu[13] also stated that TNC concentrations were low in culms when rices were grown under high or high-to-low temperature regimes. Yoshida[25] pointed out the possible contribution of stored carbohydrates to rice yield was large at low nitrogen levels or when light intensity after heading was low. As the second crop rice in Taiwan receives less N fertiliza-

tion and is under low solar radiation at the grain-filling period, it is meaningful to attempt increasing TNC in plant tissues by improving cultural practices or by variety selection in order to enhance rice yield in the second crop season.

It is widely recognized that N is essential in promoting tillering of rice plant. Fig. 3 showed that rices grown in the first crop season had higher N concentration in either leaves or culms at tillering stage than those grown in the second crop season. Such difference may be one of the factors in restricting the tillering capacity of the second crop rice. Thenabadu (cf. 23) suggested a critical N value of 2.4% in the most recently matured leaf when rice plant was at the stage of growth between maximum tillering and panicle emergence. Results of this report showed that the average N concentrations of all leaves of the second crop rice were well beyond the critical level, indicating the presence of sufficient nitrogen at this stage. Furthermore, N concentrations in leaf blades of the second crop rice were comparable or even higher than those of the first crop rice at stages close to heading. However, Lin[10] and Lin and Su[11] found that physiological characters related closely to N nutrition, such as chlorophyll concentration and photosynthetic activity, for rices in the second crop were inferior to those in the first crop. It is probable that composition of N compounds was different between the two crop rices. In other words, whether a proper proportion of N-containing compounds is in functional or active form might be important in dealing with the poor growth of the second crop rice.

Murata[14] reported that N applied at earlier stage of growth was effective in increasing the carbohydrate accumulation at maturity, but N applied at later stage of growth was effective only when the level of N at earlier stage was not too high. He also concluded that low N-response rice varieties tended to be superior in N accumulation but inferior in their ability of carbon assimilation. These assumptions were in accordance with the results of this experiment as the first crop rice had higher N concentrations at the vegetative phase and accumulated more TNC in culms during the reproductive growth stage. More information is still needed in interpreting N-C interaction because the effect of N levels on TNC metabolism had not been tested in this experiment.

Phosphorus was also necessary to promote tillering of rice (Dr. T. F. Chiu, TARI, personal communication) and was essential in carbohydrate metabolism[3]. Results on P of this study was erratic, however, the first crop rice tended to have higher concentrations except in the early developmental period. Deposition of P into culms and the sharp increase in leaves before heading suggested active carbohydrate interconversions and accumulation in plant tissues.

Lian[6] reported the retardation of K uptake of the second crop rice, resulting in lower K concentrations in plant. Similar results were found in this experiment. As the major element required for growth, K is accumulated at high concentrations by plants. It is also essential for the breakdown and formation of starch and the translocation of chemical constituents among organs. The high K concentrations in the first crop rice (Fig. 5) might indicate active carbohydrate metabolism and redistribution which were

possibly beneficial to the development of panicles before and after heading. Greater response to K fertilization of the second crop rice was demonstrated by Lian[6], indicating insufficient supply of this element for normal functioning. Further studies will be made in this laboratory to explore connections between K requirement and the biochemical processes of protein and carbohydrate metabolism grown in the second crop season.

In conclusion, we suggest that less amount of total nonstructural carbohydrates stored in culms and leaf sheaths before the onset of panicle emergence, lower concentrations of potassium in vegetative organs, and the composition, rather than concentration, of nitrogen present in plant fractions, especially leaf blades, are some of the physiological problems must be solved in order to obtain a higher yield of the second crop rice in Taiwan.

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Literature Cited

1. Association of Official Agricultural Chemists. 1970. Official methods of analysis (11th ed.). Method 3.060. The Association : Washington, D. C.
2. Cock, J. H. and S. Yoshida. 1972. Accumulation of ^{14}C-labelled carbohydrate before flowering and its subsequent redistribution and respiration in the rice plant. Proc. Crop Sci. Soc. Japan 41 : 226-234.
3. Epstein, E. 1972. Mineral nutrition of plants : principles and perspectives. John Wiley& Sons, Inc., New York.
4. International Rice Research Institute. 1972. Annual report. Los Banos, Phillipines.
5. Issac, R. A. and J. B. Jones, Jr. 1972. Effects of various dry ashing temperatures on the determination of 13 nutrient elements in five plant tissues. Comm. Soil Sci. Plant Anal. 3 : 261-269.
6. Lian, S. 1978. An investigation on yield decline in the second rice crop as affected by soil and relating factors. J. Agri. Assoc. China NS 101 : 35-55. (in Chinese with English summary)
7. Lian, S. and A. Tanaka. 1967. Behaviour of photosynthetic products associated with growth and grain production in the rice plant . Plant Soil 26 : 333-347.
8. Lian, S., Y. L. Wu and H. T. Chen. 1969. Growth performance and yield of the rice plants in the first and second crop seasons in Pingtung area. J. Taiwan Agri. Res. 18 : 1-16. (in Chinese with English summary)
9. Lian, S. and H. T. Chen. 1970. Comparison on growth performance and yield of Chianan 8 and IR 8 in Pingtung area. J. Taiwan Agri. Res. 19 : 51-61. (in Chinese with English summary)
10. Lin, A. C. 1979. Comparison on the photosynthesis under community conditions between the first and second crops of rice. *In* The causes of low yield of the second crop rice in Taiwan and the measures for improvement (S. C. Hsieh and D. J. Liu ed.). Natl. Science Council, R. O. C. (in Chinese with English summary)
11. Lin, A. C. and H. Su. 1976. Studies on the causes of low yielding in the second crop of rice in Taiwan. I. Comparison of the photosynthesis under community conditions between first and second crop of rice. Natl. Science Council Monthly 4 (11) : 5-21. (in Chinese with

English summary)

12. Lin, M. L. and K. S. Tai. 1979. Comparative studies on the accumulation of photosynthetic products and panicle growth process of the first and second rice crops in Pingtung area. Natl. Sci. Council Monthly 7 (4) : 394–400. (in Chinese with English summary)
13. Liu, D. J. 1979. Influence of temperature at various growth stages on the accumulation and translocation of carbohydrates in rice plant. *In* The causes of low yield of the second crop rice in Taiwan and the measures for improvement (S. C. Hsieh and D. J. Liu ed.). Natl. Sci. Council, R. O. C. (in Chinese with English summary)
14. Murata, Y. 1968. Physiological responses to nitrogen in plants. *In* Physiological aspects of crop yield (J. D. Estin *et al.* ed.). Amer. Soc. Agron., Madison, Wisc.
15. Murayama, N., M. Oshima and S. Tsukahara. 1961. Studies on the metabolism of rice plant during the ripening period. VI. Marking of accumulated carbohydrates in the stem and research on their translocation by use of 14-C. J. Sci. Soil Manure Japan 32 : 261–265.
16. Oshima, M. 1966. Translocation and redistribution of the assimilated 14-C in rice plant. J. Sci. Soil Manure Japan 37 : 589–593.
17. Perez, C. M., E. P. Palmiano, L. C. Baun and B. O. Juliano. 1971. Starch metabolism in the leaf sheaths and culm of rice. Plant Physiol. 47 : 404–408.
18. Raguse, C. A. and D. Smith. 1965. Carbohydrate content in alfalfa herbage as influenced by methods of drying. J. Agri. Food Chem. 13 : 306–309.
19. Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Wis. Agri. Exp. Sta. Res. Rep. 41, 11pp.
20. Stoy, V. 1963. The translocation of 14-C labelled photosynthetic products from the leaf to the ear in wheat. Physiol. Plant. 16 : 851–866.
21. Stoy, V. 1965. Photosynthesis, respiration and carbohydrate accumulation in spring wheat in relation to yield. Pihysol. Plant. Supplementum IV.
22. Tai, K. S. 1978. Improvement of the low yielding of second rice crop in Kaohsiung and Pingtung area. 2. Physiological behaviour of delaying sowing date of second rice crop. J. Agri. Assoc. China NS 102 : 24–42. (in Chinese with English summary)
23. Westfall, D. G., W. T. Flinchum and J. W. Stansel. 1973. Distribution of nutrients in the rice plant and effect of two nitrogen levels. Agron. J. 65 : 236–238.
24. Wu, H. P., I. Y. Liao, M. H. Chien, T. L. Lin, Y. S. Chen, Y. P. Wang, K. H. Tsai, L. K. Wu, W. L. Chang, F. H. Lin and Y. L. Wu. 1975. The investigation on the causes of low yielding in the second crop of rice. Natl. Sci. Council Monthly 3 (10) : 5–39.
25. Yoshida, S. 1972. Physiological aspects of grain yield. Ann. Rev. Plant Physiol. 23 : 437–464.
26. Yoshida, S. and S. B. Ahn. 1968. The accumulation process of carbohydrate in rice varieties in relation to their response to nitrogen in the tropics. Soil Sci. Plant Nutri. 14 : 153–162.

期作間水稻不同器官內碳水化合物與氮磷鉀濃度變化比較[1]

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摘　要

本試驗在臺北與臺中二地區進行，於水稻生育各重要階段測定不同器官內之非構造性碳水化合物、氮、磷與鉀濃度，並比較期作間之差異，以明瞭臺灣地區二期作水稻低產的生理原因。

水稻之稈與葉鞘，在幼穗分化與發育期間，明顯的累積非構造性碳水化合物（TNC），1978年臺中地區試驗發現，一期作水稻於抽穗前 15 天之 TNC 濃度最高，二期作則於抽穗前28天最高；1976—1977年臺北地區兩期作均於抽穗時達到最高濃度。期作間之比較顯示，一期作水稻抽穗期稈部貯存之碳水化合物總量遠超過二期作。

水稻葉片部位之氮素濃度較高，但稈與葉鞘之磷、鉀濃度超過葉片。一期作生育初期葉片之氮濃度高於二期作，但至幼穗發育階段，差異已不明顯，二期作甚至有偏高的趨勢。葉片與稈部之鉀濃度方面，則任何生育階段均以一期作爲高。水稻於抽穗前貯存之碳水化合物不足，葉片內較低的鉀濃度，以及植株內氮素的組成而非濃度，可能爲二期作水稻低產的重要生理原因。

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Nitrogen distribution and N_2 -fixing activity of developing soybean (*Glycine max* (L.) Merrill) Plants[1]

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Abstract : Field experiments were conducted to investigate the distribution of N and the specific activity of N_2-fixation of soybeans at successive stages of plant development. Nitrogen concentration in leaf blades was consistently higher than those in leaf petioles, stems and roots. Concentration in each plant part, except the seeds, usually decreased as the season progressed. However, N in leaf blades showed a sudden decline at V7 stage and an increase later at R2 stage. Pattern of changes in N in plant parts from different varieties usually was similar.

During the pod-filling period (R4-R6), N was redistributed to seeds from vegetative tissues. Shih-Shih and Kaohsiung No. 3 maintained a higher level of N in leaf blades in this period as compared with other varieties. This was coincident with high N_2-fixing activities of the two varieties at early reproductive growth stages.

Specific activities of N_2-fixation increased continuously after the formation of root nodules and reached a maximum level at V7 stage. Varietal differences in degree of symbiotic fixation were also recorded.

Comparison of N distribution between spring and summer crops showed similar trends of N fluctuation. Translocation of N to seeds was more efficient in the spring crop for Shih-Shih and in the summer crop for Tainung No. 4 as indicated by decreasing N concentration in leaf blades.

A proper N supply is essential to the growth of soybean plants as it maintains normal metabolic processes on the one hand, and provides N source to the developing protein-rich seeds on the other. Hanway and Weber [8] reported that approximately half of the N, P and K in the mature seeds were translocated from other plant parts, and the remaining half taken up from the soil and nodules during seed development. Egli *et al.* [4] also pointed out that leaves and pod walls were the major sources of redistributed N. A hypothesis proposed by Sinclair and de Wit [11,12] suggested that the redistribution of N played an important role in the senescence process in plants such as soybeans which produced high protein seeds. They further suggested that such redistribution was a

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result of the inability of roots and nodules to meet the N demand of the developing seeds. In other words, the distribution and accumulation of N in plant parts, especially in the pod-filling period, are important factors in affecting the development and yield of soybeans[13]. Higher grain yield with foliar application of N, P, K and S apparently resulted from resupplying the depleted nutrients as reported by Garcia and Hanway[6].

Most leguminous plants possess the ability to fix a considerable amount of N from atmosphere and to utilize the fixed N at high efficiency. Due to the negative relationship between soil-applied fertilizer N and symbiotically fixed N, soil fertilization of soybeans is not an economically feasible way for increasing grain yield[14]. A preliminary survey of N_2-fixation by soybean plants grown in Taiwan has been reported by the Asian Vegetable Research and Development Center[1,2]. However, little information is available on varietal differences, environmental impacts, and its relation to N and carbohydrates accumulated by the developing plants. A series of experiments were thus conducted in this laboratory to fully understand soybean physiology and to provide references for improving cultural practices and yield of soybean crop. This paper reported the N_2-fixing activities and N distribution in soybeans at successive stages of plant development. Comparisons were also made among varieties and between crop seasons. Results on total nonstructural carbohydrates will be published in a separate paper.

Materials and Methods

Soybean varieties Shih-Shih and Tainung No. 4 were grown in the spring crop season of 1979. Four additional varieties, Wakasima, Palmetto, Chunghsing No. 3 and Kaohsiung No. 3, were also planted in the summer crop season of 1979. All the experiments were conducted in the experimental farm of Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Experiments were set in 3 X 4.5 m plots with 5 replications in a randomized complete block design. Planting density was 50 X 10 cm. N, P_2O_5 and K_2O at the rate of 24, 54 and 96 kg/ha, respectively, were applied to the field at the time of sowing.

Samplings were made at V3, V5, V7, R2, R4, R6 and R8 stages according to Fehr *et al.*[5] for determining N_2-fixing activities and N concentrations. Whole plants including roots with soils were taken from field to the laboratory, cleaned with tap water and dried with towels. The root portion was then separated and inserted into a stoppered glass flask of known volume. One-tenth of volume of air was removed from the flask with an injector and refilled with same volume of acetylene. 0.5ml of gas sample was taken after 30 min. of reaction and acetylene reduction was determined with a Pye Unicam's Pye Series 104 gas chromatograph[9]. Conditions of GC operation were: column-alumina oxide, column temperature-100°C, detector temperature-100°C, H_2 flow rate-50 ml/min., carrier gas (air) flow rate-750 ml/min. A standard curve prepared from ethylene was plotted for comparison. N_2-fixing activity was calculated by dividing the amount of ethylene formed by 3 and was expressed as μmoles N_2 fixed/g. fresh nodule/hr.

For N determination, the whole plant was divided into leaf blade, petiole, stem, pod wall, seed, root and nodule fractions. Samples were dried in an air-drafted oven at

100°C for 2 hrs followed by 80°C for 48 hrs, and ground in a Wiley mill through a 40-mesh screen. Nitrogen was then determined by semi-micro Kjeldahl procedures.

Results and Discussion

With few exceptions, N concentrations in various plant parts were similar for the six varieties grown in the summer crop season of 1979. Hanway and Weber [7] also found that composition of major elements in plant parts from different soybean varieties showed no significant difference. Therefore, N concentraions of some tissue fractions were averaged from the six varieties and shown in Table 1. Leaf blades were comparable to nodules and were higher than petioles, stems and roots in terms of N concentration throughout the whole developmental course of soybean plants. Nitrogen ranged between 4 to 5% in leaf blades up to R4 stage (pod 2 cm long at one of the four uppermost nodes with a completely unrolled leaf), which was in accordance with the result of Brevedan *et al.* [3] and Terman [13]. With the only exception of Palmetto, the other five varieties showed a sudden decrease in N concentration at V7 stage (7 nodes on the main stem beginning with the unifoliolate node) and a marked increase later at R2 stage (flower at node immediately below the uppermost node with a completely unrolled leaf). Studies by Hanway and Weber [7] also indicated that for non-nodulating soybean isolines, there was a drop of leaf N concentration at full bloom stage followed by an increase when pods were plainly evident in top of plants. Whether this change in leaf N concentration was specific during the transition period from vegetative to reproductive growth or a result from rapid accumulation of dry matter has yet to be determined.

Nitrogen concentration in leaf blades decreased consistently from R2 to R8 (harvest maturity) stage and the decline was most conspicuous during pod-filling period (R4-R6). Concentration of N of the six varieties at harvest ranged between 2.41 to 3.06% (average 2.66%) which was higher than that reported by Jeppson *et al.* [10] (1.51-1.98%) but was similar to the result of Terman [13] (2.02-3.27%). Approximately half the N in the mature, protein-rich seeds had been accumulated earlier in other plant parts and was then translocated to the beans [8]. Leaf blades had also been demonstrated as the main source of the redistributed N [4]. The concomitant occurrence of decreasing leaf N and increasing seed N during pod-filling stage, as shown in Tables 1 and 2 of this experiment, further suggested the dependence of soybean seeds on leaf blades for N supply.

Table 1 also showed that N concentrations in leaf petioles, stems and roots were similar and ranged between 0.5 to 2.0% from early development to maturity. In general, concentrations peaked at early vegetative growth stage (V3) and declind thereafter. Decreases in N were most evident in the periods of V3-V5 and R4-R8 for petioles and stems and V5-V7 and R4-R8 for roots. In other words, significant decrease in N percentages during pod-filling was found not only in leaf blades but also in other vegetative plant fractions. It has been reported [4] that stems and petioles of soybean plants were capable of supplying a limited portion of N needed by the developing seeds. It was also probable that root was one of the organs involved directly in N redistribution caused by

the rapid development of soybean seeds. Furthermore, the decline of N concentration accompanied by less accumulated carbohydrates (unpublished data) might lead to the loss of physiological activity of roots in late developmental period of soybean plants.

Table 1. Average nitrogen concentration (%, dry basis) in different plant parts of six soybean varieties at several stages of development (summer crop, 1979)

Plant Part	Developmental Stage						
	V3	V5	V7	R2	R4	R6	R8
Leaf blade	4.40	4.64	3.91	4.55	4.80	3.34	2.66
Petiole	2.07	1.53	1.14	1.15	1.08	0.85	0.52
Stem	1.76	1.28	1.07	1.24	1.13	0.72	0.47
Root		1.55	1.29	1.16	1.14	0.85	0.60
Nodule		4.78	4.41	4.42	4.28	3.68	

Highest N concentration in root nodules was also found at early vegetative growth stage (Table 1). It was 4.78% at V5 (5 nodes on the main stem) and 3.68% at maturity. The decline was less significant as compared with those of other plant parts. The presence of root nodules is of paramount importance as nodules are the site of biological N_2-fixation. The fixed N is converted to other N-containing compounds and translocated acropetally to the above-ground tissues. However, changes in N concentration in root nodules *per se* was not significant to the redistribution of N in soybean plants at pod-filling stage because of the low dry weight contributed by the nodules. Cross sections of root nodules at R6 stage indicated the degeneration and disappearance of leghaemoglobin which is closely related to the ability of N_2-fixation. The relationship between N concentration and N_2-fixing activity of root nodules was another subject remained to be studied.

Table 2 showed N concentrations in leaf blades, pod walls and seeds of soybean varieties between R4 and R8 stages. The phenomenon and importance of declining N concentration in leaf blades have been described earlier. Pod walls at R4 stage contained 3.63-4.28% (average 3.86%) of their dry weight as N. The values decreased to 0.92-2.04% (average 1.47%) at R6 and 0.49-0.89% (0.64%) at R8 stage. On the other hand, average N concentration in seeds was 3.86, 6.34 and 6.23%, respectively, at R4, R6 and R8 stages. These results indicated that large amount of N were exported from leaf blades and pod walls to the developing seeds. Egli *et al.* [4] reported that 27-56% of total redistributed N was contributed by leaf blades, 32-45% contributed by pod walls, and 3-8% by leaf petioles. The stems contributed about 12% under N-stress condition but none under normal or high N-fertilization.

Table 2. Nitrogen concentration (%, dry basis) in pods, seeds and leaf blades of six soybean varieties at several reproductive growth stages (summer crop, 1979)

Variety	Leaf blade			Pod Wall			Seed	
	R4	R6	R8	R4[a]	R6	R8	R6	R8
Wakasima	4.99	3.19	2.41	3.63	1.22	0.60	6.00	6.16
Tainung No, 4	4.67	2.67	2.46	3.70	1.41	0.89	6.46	6.54
Shih-Shih	4.29	4.11	2.54	4.28	2.04	0.49	6.42	5.92
Kaohsiung No, 3	5.36	3.61	2.70	3.83	1.40	0.69	6.10	6.02
Palmetto	5.20	3.40	3.06	3.99	1.82	0.50	6.49	6.11
Chunghsing No. 3	4.30	3.06	2.78	3.74	0.92	0.64	6.55	6.61

[a]. Including seeds at early developmental stage.

Comparisons among varieties were also shown in Table 2. For N concentration in leaf blades at R6 stage, Shih-Shih (4.11%) and Kaohsiung No. 3 (3.61%) were significantly higher than the other four varieties(average 3.11%). Pod walls of Shih-Shih were also higher in N at R4 and R6 stages (4.28 and 2.04%, respectively). Egli *et al.* [4] found that increasing the supply of N to soybean plants during the pod-filling period had no effect on the amount of N redistributed to the seeds and suggested that the redistribution could not be prevented by increasing N available to the root system. It is therefore possible that varietal differences in N distribution might be affected by the genetically controlled absorption ability of roots. In addition, the N_2-fixing activities of Shih-Shih and Kaohsiung No. 3 at R4 stage were, respectively, 2.24 and 3.12 umoles N_2 fixed/g. fresh nodule/hr which were one to two times higher than those of the other varieties at the same growth stage (Table 3). The resulted higher amount of fixed N might be helpful in maintaining leaf N concentration and hence physiological activity. It was suggested that active N_2-fixation at pod-filling period was important to the grain yield of soybean crop.

Activities of N_2-fixation of the six soybean varieties at several developmental stages were shown in Table 3. The activity increased on a per gram fresh nodule basis in the vegetative growth phase and decreased then toward maturity. Highest values in this experiment ranged between 3.17 to 4.93 μmoles N_2 fixed/g. fresh nodule/hr which were recorded at V7 stage. The amount of N fixed by one gram fresh nodule per hr decreased to 0.91-2.68 μmoles at R2 and was lower than 1 μmole at R6 stage. According to the report of Asian Vegetable Research and Development Center (AVRDC) in 1975 [1], the activity of soybean accession 2120 was highest during the 7th week after planting with a gradual reduction afterwards (flowering occurred during the 10th and 11th weeks, pod filling was initiated the 12th). A report in 1976 by AVRDC [2] showed that the general pattern of acetylene reduction activity of soybean accession 38 was similar in both spring and fall croppings. Detectable only from the 4th week after planting, the activity peaked at between 8 and 9 weeks which coincided with flowering and early pod formation. The N_2-fixing activity obtained in this experiment was earlier in reaching the maximum

level (V7) when compared with the results of AVRDC. The specific activity might also be higher for the soybean varieties grown in Taichung area.

Varietal differences in fixing N for soybeans grown under similar environmental conditions and cultural practices could also be elucidated from Table 3. At V7 stage, the N_2-fixing activity was highest for Palmetto (4.93 μmoles N_2 fixed/g. fresh nodule/hr) and lowest for Tainung No. 4 (3.17). However, the activities of Palmetto and Chunghsing No. 3 decreased to 1.51 and 1.37 units, respectively, during pod-filling stage (R4) which were higher than the 0.98 units of Tainung No. 4 but significantly lower than those of Shih-Shih (2.24) and Kaohsiung No. 3 (3.12). The performance of Shih-Shih was different from those of other varieties by maintaining high N_2-fixing activity from V7 to R4 stgae. Although Kaohsiung No. 3 possessed high ability in fixing N at V7 and R4, there was a drastical decrease in specific activity at R2 stage. The high activity of N_2-fixation of Shih-Shih in early reproductive period (R2-R4) might be helpful in maintaining part of the leaf N from exporting to the seeds and therefore delaying senescence and keeping relatively active physiological activities of the vegetative organs.

Table 3. N_2-fixing activity (micro-moles N_2 fixed/g. fresh nodule/hr) of developing soybean plants (summer crop, 1979)

Variety	Developmental Stage				
	V5	V7	R2	R4	R6
Wakasima	0.94	3.91	1.82	1.63	0.15
Tainung No. 4	1.24	3.17	2.22	0.98	0.26
Shih-Shih	2.75	3.78	2.68	2.24	0.44
Kaohsiung No. 3	2.44	4.30	1.90	3.12	0.63
Palmetto	1.52	4.93	1.38	1.51	0.07
Chunghsing No. 3	1.39	3.63	1.77	1.37	0.28

Table 4 compared the N concentrations in different plant parts of Shih-Shih variety grown in the spring and summer crop seasons of 1979. During the vegetative growth period, no seasonal effect was found on the N concentration in leaf blades. The spring crop was higher in stem and petiole N concentrations than the summer crop. In the reproductive growth period, leaf N concentration was lower at R2 but higher at R6 in the summer than in the spring crop. Leaf petioles and stems at R4-R8 and pod walls at R6 stage were also higher in N for Shih-Shih soybean grown in the summer season. Whether these were the results of high N_2-fixing activity (Table 3) could not be determined because the spring crop was not analyzed for its ability in N_2-fixation. Nitrogen in mature seeds was similar for the two crops although a marked difference existed between the spring (5.37%) and summer (6.42%) crops at R6 stage.

Results on Tainung No. 4 soybean showed no consistent variation in N concentration between crop seasons (Table 5). However, summer crop contained less N in leaf blades, petioles and stems at V7-V8 stages, a phenomenon also observed in Shih-Shih (Table

4). In the period of rapid pod-filling when N was redistributed among plant parts, N levels in vegetative organs (except pod walls) of the summer soybean decreased more significantly than those of the spring crop. This was presumably due to the efficient translocation of N in the summer season or the result of prolonged rainfall at late developmental stage of the spring crop.

Table 4. Nitrogen concentration (%, dry basis) in different tissue fractions of developing soybean plants grown in the spring and summer crop seasons, 1979 (var. Shih-Shih)

Tissue Fraction	Crop Season	Developmental Stage							
		V2[a]	V3-V4[a]	V5-V6[a]	V7-V8[a]	R2	R4	R6	R8
Leaf	Spring	4.19	4.22	4.24	3.97	4.51	4.27	3.45	—
	Summer		4.20	4.27	4.07	4.17	4.29	4.11	2.54
Petiole	Spring	2.18	2.16	1.76	1.38	1.19	1.14	0.72	0.48
	Summer		1.95	1.41	1.25	1.11	1.24	1.13	0.60
Stem	Spring	2.07	1.50	1.39	1.28	1.22	1.22	0.77	0.44
	Summer		1.34	1.20	1.25	1.22	1.32	1.15	0.53
Pod Wall	Spring						4.24[b]	1.32	0.54
	Summer						4.28[b]	2.04	0.49
Seed	Spring							5.37	5.82
	Summer							6.42	5.92

a. Samples were taken at V3, V5 and V7 stages for summer crop, and at V2, V4, V6 and V8 stages for spring crop.

b. Including seeds at early developmental stage.

A general survey revealed that for the two varieties tested, absolute N concentrations in various plant fractions were comparable between crop seasons up to the R4 stage. Leaf N of Tainung No. 4 decreased from 4.67% to 2.67% between R4 and R6 stages in the summer whereas the decrease was from 3.98% to 3.61% in the spring (Table 5). On the contrary, changes in leaf N of Shih-Shih during the same period were more rapid in the spring than in the summer crop (Table 4). Shih-Shih is an early-maturing variety widely adapted in Taiwan while Tainung No. 4 is mid to late-maturing. Their responses to environmental factors might therefore be different when grown in both the spring and summer crop seasons.

Table 5. Nitrogen concentration (%, dry basis) in different tissue fractions of developing soybean plants grown in the spring and summer crop seasons, 1979 (var. Tainung No. 4)

Tissue Fraction	Crop Season	Developmental Stage							
		V2[a]	V3-V4[a]	V5-V6[a]	V7-V8[a]	R2	R4	R6	R7-R8[a]
Leaf	Spring	4.50	4.35	4.50	4.02	4.60	3.98	3.61	2.28
	Summer		4.31	5.01	3.75	4.74	4.67	2.67	2.46
Petiole	Spring	2.32	2.29	1.85	1.33	1.23	1.01	0.79	0.50
	Summer		2.21	1.75	1.06	1.22	1.08	0.67	0.53
Stem	Spring	2.68	1.78	1.50	1.31	1.09	1.11	1.09	0.43
	Summer		2.04	1.36	0.36	1.38	1.05	0.72	0.48
Pod wall	Spring						3.61[b]	1.45	0.58
	Summer						3.70[b]	1.41	0.89
Seed	Spring							5.61	5.81
	Summer							6.46	6.54

a. Samples were taken at V3, V5, V7 and R8 stages for summer crop, and at V2, V4, V6, V8 and R7 stages for spring crop.
b. Including seeds at early developmental stage.

Terman[13] pointed out that maximum dry matter yields and nutrient uptake of soybeans occurred during the early pod-filling stage of growth. Hanway and Weber[8] found N, P and K accumulated during the 46-day period between full bloom to near maturity accounted for 75 to 80% of the total accumulation of these nutrients. These results indicated the importance of maintaining active physiological activities in the reproductive growth stage. Due to the facts that increasing nutrients available to the root system could not prevent the loss of N from vegetative organs to the developing seeds [4,7] and the rapid and continuous decline in N_2-fixing activity (Table 3), higher grain yield might be achieved if a better balanced nutritional status in soybean plants was maintained through increasing both the absorption ability of roots and the activity of N_2-fixation in the late developmental period.

The contribution of N_2-fixation to soybean yield has been overlooked in Taiwan because of the low price of chemical fertilizers. Report of AVRDC[2] showed that total N accumulated in the plant was highly correlated with the cumulative acetylene reduction activities ($r = 0.97^{**}$). Hanway and weber[7] also noted that the loss of N from other plant parts to the seeds could not be altered even 672 kg N/ha was applied to the soil. Both reports suggested that the symbiotically fixed N, rather than fertilizer N, was used more efficiently by the soybeans. This study has found that differences in ability of fixing N from atmosphere existed among the soybean varieties currently grown in Taiwan. As the growth of soybeans is sensitive to environmental conditions[1,2,3,6,14] and the N status is affected by the presence of other elements[7,8], more information is required for a better understanding of fertilization efficiency and nutritional problems of plants.

Literature Cited

1. Asian Vegetable Research and Development Center. 1975. Soybean report. The Center, Shanhua, Taiwan, R. O. C.
2. Asian Vegetable Research and Development Center. 1976. Soybean report. The Center, Shanhua, Taiwan, R. O. C.
3. Brevedan, R. E., D. B. Egli and J. E. Leggett. 1977. Influence of N nutrition on total N, nitrate and carbohydrate levels in soybeans. Agron. J. 69:965-969.
4. Egli, D. B., J. E. Leggett and W. G. Duncan. 1978. Influence of N stress on leaf senescence and N redistribution in soybeans. Agron. J. 70:43-47.
5. Fehr, W. R.. C. E. Caviness, D. T. Burmood and J. S. Pennington. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Sci. 11:929-931.
6. Garcia, R. L. and J. J. Hanway. 1976. Foliar fertilization of soybeans during the seed-filling period. Agron. J. 68:653-657.
7. Hanway, J. J. and C. R. Weber. 1971a. N, P, and K percentages in soybean (*Glycine max* (L.) Merrill) plant parts. Agron. J. 63:286-290.
8. Hanway, J. J. and C. R. Weber. 1971b. Accumulation of N, P, and K by soybean (*Glycine max* (L.) Merrill) plants. Agron. J. 63:406-408.
9. Hardy. R. W. F., R. D. Holsten, E. K. Jackson and R. C. Burns. 1968. The acetylene-ethylene assay for N_2 fixation : laboratory and field evaluation. Plant Physiol. 43:1185-1207.
10. Jeppson, R. G., R. R. Johnson and H. H. Hadley. 1978. Variation in mobilization of plant nitrogen to the grain in nodulating and non-nodulating soybean genotypes. Crop Sci. 18:1058-1062.
11. Sinclair, T. R. and C. T. de Wit. 1975. Comparative analysis of photosynthate and nitrogen requirements in the production of seeds by various crops. Science 189:565-567.
12. Sinclair, T. R. and C. T. de Wit. 1976. Analysis of the carbon and nitrogen limitations to soybean yield. Agron. J. 68:319-324.
13. Terman, G. L. 1977. Yields and nutrient accumulation by determinate soybeans, as affected by applied nutrients. Agron. J. 69:234-238.
14. Welch, L. F., L. V. Boone, C. G. Chambliss, A. T. Christiansen, D. L. Mulvaney, M. G. Oldham and J. W. Pendleton. 1973. Soybean yields with direct and residual nitrogen fertilization. Agron. J. 65:547-550.

大豆品種間固氮作用活性與氮素分佈之比較[1]

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摘　　要

試驗目的在探究大豆品種植株內氮素之分佈，以及固氮作用活性的變化，藉以明瞭大豆各生育期之營養需求。葉片內之氮濃度顯著高於葉柄、莖及根部，而與根瘤相近；除種子外，各器官內氮素濃度多隨植株之發育而逐漸降低，唯葉片 V7 期有顯著降低，R2 期再大幅上升的現象；各品種間未呈差異存在。莢果充實期 (R4-R6) ，營養器官內氮素可轉移至種子，但十石與高雄三號葉片內氮素濃度高於其他品種，可能與生殖生長期仍具有較高之固氮作用活性有關。大豆固氮活性自根瘤形成後逐漸上升，V7 期達於高峰，開花後隨即下降，但品種間有程度性差異。春夏作之栽培結果顯示氮素營養變化模式並無明顯之期作性差異，而葉片內氮素於子粒充實期間之轉移速率則有不同。大豆生殖生長過程中，植株內有效性氮化合物大量減少，根部根瘤固氮作用能力亦低，可能不利於生理活性之維持。

1. 臺灣省農業試驗所 研究報告 第 918 號。本試驗承行政院農業發展委員會補助，謹此誌謝。
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Strong acid treatment for making smears of tobacco microspores [1]

Hsin-Sheng Tsay [2]

Abstract : A procedure developed for identifying the developmental stage of tobacco microspores is described. Fixation in Carnoy's solution (ethanol, chloroform, acetic acid, 6 : 3 : 1) for at least 30 min is followed by soaking in 70% ethanol. Storage, if necessary, at 5-8°C is recommended. Maceration in a 2 : 1 : 1 mixture of 15% CrO_3, 10% HNO_3, and 5% HCl for 7-10 min. is required to remove spore walls. Hardening is then done in 1 : 1 95% ethanol-propionic acid and staining in 1% aceto-carmine for 20-30 min.

The developmental stage at which anthers are excised and cultured is one of the most critical factors for androgenesis. Generally, it occurs somewhere around first pollen mitosis in tobacco (4,6,7,8). The conventional methods of fixing and staining at this stage leave the walls of the spore intact. As the spore wall of microspore always stains intensely and causes poor contrast, sometime it is difficult to ensure the exact microspore stage. Burns and Yang recommended the use of acid maceration method of handling the microspores of *Nicotiana* (3), Bernardo described the use of CrO_3 in conjunction with HNO_3 and HCl were satisfactory for the preparations of the thicker-walled *Gossypium* microspores (1). The present technique adopts these reagents for removing the spore walls.

The procedures shown below were developed according the Bhadure and Majumdar (2), Burns and Yang (3), Bernardo (1), Jagathesan and Sreenivasan (5) for identifying the development stages of tobacco microspores :

1. Fix anthers in Carnoy's solution for 30 min.
2. Transfer to 70% ethanol, store at 5—8°C if necessary.
3. Rinse with 30% ethanol for 15 min.
4. Rinse with distilled water for 30 min.
5. Hydrolyze in 1 N HCl at 60°C for 10 min.
6. Rinse in distilled water
7. Macerate in drop of water on slide.
8. Squash anther, remove anther wall and apply cover-slip.

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9. Rinse and clear tapetal cells by passing water from one side of cover slip to another with aid of blotting paper.

10. Dissolve exine by introducing freshly prepared 2 : 1 : 1 mixture of 15% CrO_3 : 10 % HNO_3 : 5% HCl under cover slip and let stand for 7—10 min. The time element of strong acid treatment is very critical. If the treating time by strong acid is too short, the spore wall will not be sufficiently removed. On the other hand, after the sporewall has disappeared the entire cell contents will disintegrate within a few minutes. For our purpose, 7—10 min. in the acid solution at room temperature (ca. 26°C) is adequate. The proper timing can be determined by observing under low magnification of a microscope. Upon the disappearance of the spore walls the slide should be rinsed with distilled water immediately.

11. Rinse slide with distilled water as in step 9.

12. After the strong acid treatment, the protoplasts are very soft. They must be hardened before the chromosomes can be stained. In tobacco microspore, the cytoplasm is hardened by displacing the distilled water with 1 : 1 mixture of 95% ethanol and propionic acid. Since hardening solution evaporates rapidly, the treatment should be continued by adding acid-alcohol at intervals of at least 3 min.

13. Stain with 1% aceto-carmine, leave in stain until cells turn red (20—30min.).

14. Place slide over alcohol lamp and heat gently.

15. Gently apply pressure onto cover slip while still hot.

16. Examine under microscope.

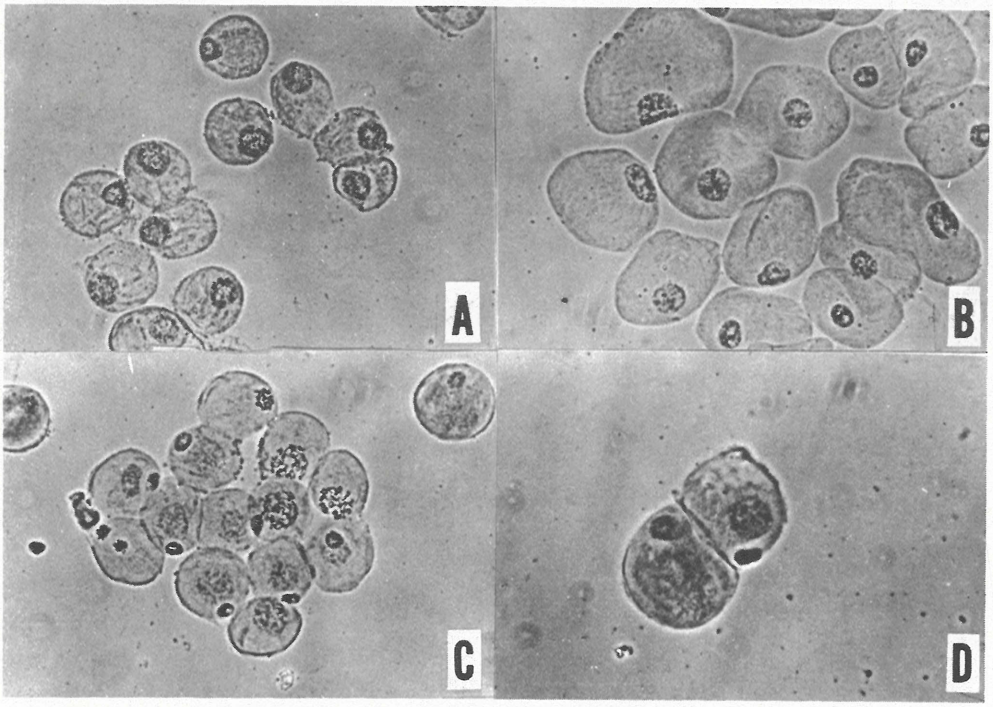

Fig. 1. The developmental stage of microspores of *N. tabacum* at early uninucleate stage (A), late uninucleate stage (B), first pollen mitosis (C), and early binucleate stage (D)by strong acid treatment (7 min,) and aceto-carmine staining preparation.

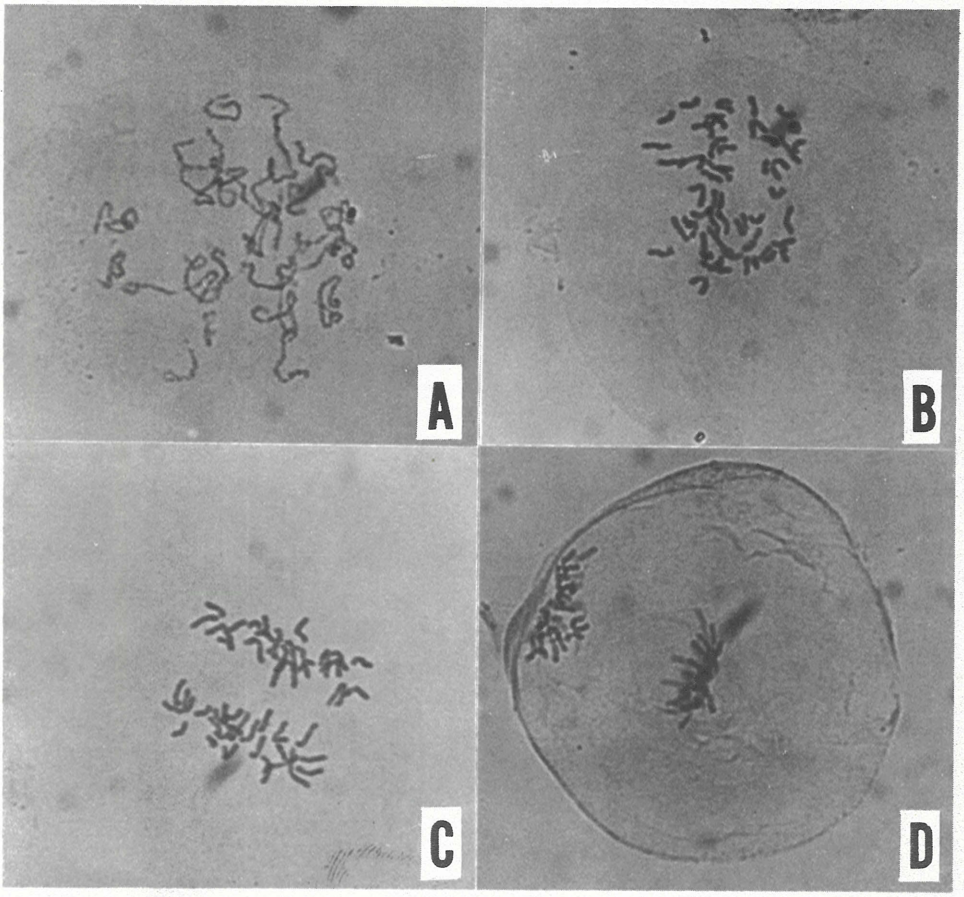

Fig. 2. The dividing pollen grain of *N. tabacum* at prophase (A), metaphase (B), anaphase (C), and telophase (D) of first pollen mitosis by strong acid treatment (10 min.) and aceto-carmine staining preparations.

Only by experiment can the technique be adjusted to produce satisfactory results in any given situation. Factors such as freshly prepared acid solution, the time needed to remove the spore wall, the time needed to wash and harden the cytoplasm and the time needed to stain may require adjusting, depending on the maturity of the spore wall.

Literature Cited

1. Bernardo, F. A. 1965. Processing *Gossypium* microspores for first-division chromosomes. Stain Techn. 40 (4) : 205-208.
2. Bhadure, P. N. and B. R. Majumdar. 1955. An improved pollen grain smear method for wheat. Stain Techn. 30 (2) : 93-98.
3. Burns, J. A. and S. J. Yang. 1961. Acid maceration as an acid in making smears of *Nicotiana* microspores. Stain Techn. 36 : 102-104.
4. Collins, G. B. and N. Sunderland. 1974. Pollen-derived haploids of *Nicotiana knightiana*, *N. raimondii* and *N. attenuata*. J. Exp. Bot. 25 (89) : 1030-1039.
5. Jagathesan, D. and T. V. Sreenivasan. 1966. A pollen grain squash technique for *Saccharum* and related genera. Stain Techn. 41 : 43-47.
6. Nitsch, J. P. 1969. Experimental androgenesis in *Nicotiana*. Phytomorphology 19 (4) : 389-404.
7. Nitsch, J. P. and C. Nitsch. 1970. Obtention de plantes haploides a partir de pollen. Bull. Soc. Bot. Fr. 117 : 339-360.
8. Sunderland, N. and F. M. Wicks. 1969. Cultivation of haploid plants from tobacco pollen. Nature 224 : 1227-1229.

菸草小胞子強酸處理之醋洋紅塗抹法[1]

蔡 新 聲[2]

摘 要

菸草小胞子不同發育時期之醋洋紅壓潰檢定法其過程如後：將菸草花葯固定於 Carnoy's 固定液中至少30分鐘，然後立即浸入70%酒精中，若需貯藏則以 5°~8°C 之溫度較爲適當，以新鮮配製 2：1：1之 15% CrO_3, 10% HNO_3 及 5 % HCl 處理小胞子 7 ~10 分鐘以溶解細胞壁，其原生質體經 1 ：1之 95% 酒精及 propionic acid 硬化 3 分鐘，再以 1 %醋洋紅染色 20~30 分鐘。

1.臺灣省農業試驗所 研究報告 第 919 號。

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中華農業研究 (Jour. Agric. Res. China) 29(2)：107～114(1980)

水稻數量性狀遺傳之研究

Ⅱ.秈粳稻品種間之完全組合互交[1]

張　德　梅[2]

摘要：本研究係利用兩種秈稻（P_1 爲嘉秈 11 號；P_2 爲臺中在來 1 號）及兩種粳稻（P_3 爲臺南 5 號；P_4 爲臺農 67 號）作試驗材料，進行全互交（包括正反雜交及自交）以研究水稻重要數量性狀之遺傳法則。玆將結果簡述如下：

一、水稻之株高、穗長、結實率及千粒重在四個親本間均有極大之遺傳變異量，雜交組合後代亦有極明顯之顯性效果，並且互交間有顯著之差異存在。

二、因各性狀遺傳因子之顯性變方 H_1 大於因子之累加性遺傳變方 D（由表 4 中之 $D-H_1$ 在各性狀均爲負值），表示顯性變方較大。又 $(H_1/D)^{\frac{1}{2}}$ 表平均顯性程度，除每穗粒數及結實率外，其他四個性狀均大於 1，表示完全顯性或超顯性。株高、穗數、每穗粒數及結實率之 $H_1 \fallingdotseq H_2$，則示 $u \fallingdotseq v$，因此，顯性程度有一部分係由顯隱性因子頻度不相等所造成。因 K_D/K_R 在穗長及千粒重等於 1，表示顯隱性因子數可能相等，其他四個性狀則否。h^2/H_2 表示顯性因子數，在各性狀均爲 1～2 對顯性因子控制顯性程度。

三、秈粳稻雜交後代中，結實率最低之組合爲 58%，最高的組合達 82%，而且在產量構成要素中之穗數，每穗粒數及千粒重等，超過高親本而達顯著之組合不少，由以往研究結果、穗數、每穗粒數及千粒重等無自交衰退之現象，而結實率又在世代選拔中有增進之效果，因此，由秈粳稻雜交後代中，可能選出優良之品系。

依據形態，血清反應及親和力等，水稻（*O. sativa* L.）分爲兩個亞種（subspecies），一稱爲日本型（*japonica* type），另一稱爲印度型(*indica* type)[13]，兩者又稱爲粳型及秈型稻。此兩亞種間的最大特性，爲其雜種 F_1 及其後代具有各種不同程度的稔實率，其變域隨雜交組合之不同而異，可由 0～100 %。此兩型稻各具有其優劣點，秈稻最大之優點爲在高溫下分蘖數較多，較抗稻熱病，缺點爲顆粒澱粉含量高，以致米質稍差；粳稻之根系活力較强[7]，較抗白葉枯病，因顆粒澱粉含量稍低，米質較好，但在高溫下分蘖數減少[1,2]及對其他病蟲害之抵抗性較差[8]。

由於同型品種間血緣較近，由其雜交所育成之新品種往往有如上述之缺點，因此本省各試驗場所在多年前，已從事於秈粳稻之雜交育種以謀改善此缺點，並已得某些成就，但仍嫌不足，故此項工作尙待加强。由於雜交育種的成敗，決定於所用雙親的遺傳組成及育種目標中某些性狀遺傳因子的表現，所以從事育種工作者，應先瞭解雙親各性狀之遺傳行爲，才能收事半功倍之效果。水稻具有經濟價值的性狀，大多爲數量性狀，故應將這些性狀之遺傳行爲加以研究並瞭解之，裨能提高秈粳稻雜交後代之選拔效果。

過去研究者[5,10,14,15,16]，利用全互交法測定水稻數量性狀之遺傳行爲，均以品種間各性狀之差異

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1. 臺灣省農業試驗所 研究報告 第 920 號。本研究承行政院國家科學委員會獎助，文成蒙謝順景主任及劉清博士斧正，謹誌謝忱。

2. 本所農藝系技士。臺灣省 臺中縣 霧峰鄉。

較大者為材料，所得結果未必能為育種時採用，而目前推廣品種數量性狀之遺傳變異甚少報導，因此為了探討栽培品種秈稉稻間數量性狀之各種遺傳法則，利用各親本間之完全組合互交法研究之，而所獲得之各種數量遺傳訊識具有普遍適用價值，對今後秈稉稻雜交育種工作當有極大裨益。

材料與方法

一、研究材料：計四品種：P_1，嘉秈 11 號、P_2，臺中在來1號、P_3，臺南5號、 P_4 ，臺農67號。進行完全組合互交而獲得 12 個 F_1 雜種。

二、研究性狀及調查方法：

（一）研究性狀：以與經濟價值有密切關係之諸性狀為主，即株高、穗數、穗長、一穗粒數、結實率及千粒重等。

（二）調查方法：(1)株高（cm）：自地面到成熟期穗頂之高度。(2)穗數（支）：單本植之有效分蘖數。(3)穗長（cm）：從穗頸到穗頂間之長度。(4)一穗粒數（粒）：一株內總粒數／總穗數。(5)結實率（%）：一株內穀粒空與實之比率。(6)千粒重（g）：1000 粒穀粒之重量。

三、試驗設計：自交及雜交所得 F_1 種子，以逢機完全區集設計，每小區包括12個 F_1 及4個自交親本，行株距為 22.5×22.5cm，單本植，四重復。

四、分析方法：以 Hayman 氏之方法為主[11,12] 及張恩雨修改前者所創對處理平方和劃分之公式估算各種遺傳變因之平方和及均方[6]。

結果與討論

一、秈稉稻各種數量性狀全互交各組合 F_1 及親本之平均值

將六個數量性狀，按照試驗計畫，以單株為單位分別調查記錄之，以試區為單位求其每 10 株之平均，並將四區集同處理相加後之平均列於表1。

由表1可知，雜交後代之六個性狀中，除結實率低於親本外，其他各性狀在 F_1 之表現均高於低親本。盧、孔[9] 曾進行稻亞種間雜種後裔之稔實率選拔，自 F_2 代起，分別向正 70 % 以上及負 40 % 以下，正負兩方向繼續行個體選拔，結果無論選拔方向如何，結實率均向高的一方漸次增進，因此，秈稉稻雜種後代結實率之恢復，在繼續行個體選拔是有希望的。又如李、張[10] 報告，水稻產量構成因子性狀，第二代羣體之平均值與第一代平均值比較，並無因自交衰退之趨勢，因此，本試驗中 F_1 之表現結果，在秈稉稻育種方面有參考價值。以下分別討論之：

（一）株高：水稻植株的高矮，在育種工作方面極具重要性，目前的推廣品種，株高多介於 85～110 cm 間，但本試驗中雜交後裔有高於親本者，如 $P_3 \times P_2$ 為 127 cm，亦有低於親本者，如 $P_1 \times P_2$ 為 85 cm。有關株高方面之遺傳研究，過去很多報導，張[4] 研究正常稻與突變矮稻以及突變矮稻與突變矮稻雜交所獲得之 F_1 ，發現植株高度均屬正常，因此可知支配株高之遺傳因子為顯性，且在 F_2 代之高矮分離比為3：1與9：7，表示分別為一對和兩對遺傳因子支配。本研究中所用親本之株高差異不大，多數組合均屬正常高度，由於正反交之結果，株高有不同程度之差異，並且在 F_2 中可能有 ¼ 和 7/16 的矮株出現，可由此雜交集團中選拔矮株品系。

（二）穗數：四個親本中，臺南5號之平均穗數略低，其他三個親本相差不大。雜種 F_1 之穗數超過親本者很少，由表1可知，以穗數多的秈稻為母本可以得到穗數多的 F_1，如 $P_1 \times P_2$ 、 $P_1 \times P_3$ 及 $P_1 \times P_4$。張[5] 報告，穗數在 F_2 代之遺傳率很低，必須在後世代中才有可能選出穗數多之品系。

（三）穗長：各親本間穗長相差不大，介於 21～23 cm 間，且同型品種間之穗長幾乎相等，因此，同型品種之 F_1，穗長無正反交差異，也未超過親本；異型品種之 F_1，穗長部分組合超親過本，

表 1. 全互交各種數量性狀各組合 F_1 及親本之平均値

Table 1. Mean values of parents (underlined) and F_1 hybrids in a 4 × 4 diallel cross

Characters	Male	Female			
		P_1	P_2	Γ_3	P_4
Plant height (cm)	P_1	90.5	84.5	111.5	109.0
	P_2	117.8	86.3	127.0	121.7
	P_3	103.2	91.0	106.2	109.0
	P_4	106.2	106.0	112.7	102.0
Panicle number	P_1	13.7	11.7	12.7	11.0
	P_2	18.0	12.7	17.5	14.2
	P_3	17.2	14.0	9.0	9.0
	P_4	16.2	10.2	13.5	12.7
Panicle length (cm)	P_1	22.2	23.7	28.2	25.8
	P_2	24.0	22.7	24.7	23.5
	P_3	22.5	25.6	21.2	20.6
	P_4	24.7	26.2	22.6	20.5
Number of spikelet per panicle	P_1	117.5	114.0	136.7	166.0
	P_2	117.7	98.2	131.7	134.5
	P_3	138.7	141.5	111.0	118.C
	P_4	111.7	172.0	131.7	119.5
Seed fertility (%)	P_1	93.7	74.9	68.0	81.5
	P_2	71.3	88.6	76.4	72.1
	P_3	75.8	57.9	92.8	91.5
	P_4	78.8	63.9	94.4	91.0
1000-grain weight (g)	P_1	22.3	23.2	22.9	25.6
	P_2	24.9	22.7	29.1	26.8
	P_3	25.3	25.5	24.5	24.6
	P_4	25.3	26.4	25.9	24.8

如 $P_3 \times P_1$ 爲 28.2 cm, $P_1 \times P_3$ 爲 22.5 cm 正反交相差 5.7 cm，其他雜交組合之差異較小。

（四）一穗粒數：水稻一穗粒數之遺傳情形與穗數相同，亦因親本間相差不大（ 2～10 粒），同型品種間之雜交後代， 正反交間無差別；異型品種間之 F_1，如 $P_4 \times P_1$ 爲 165 粒 ， $P_1 \times P_4$爲 112 粒，相差 53 粒，其他組合正反交間之差異很少。據 Wu [16] 之報告，每穗粒數與穗數之遺傳情形相同，至少受四羣基因控制，並且受環境之影響很大。

(五) 結實率：親本之結實率均很高 (89～94 %) ，同型品種間之 F_1 ，稉×稉稻組合，如 $P_3 \times P_4$ 爲 94 %，$P_4 \times P_3$ 爲 92 %；秈×秈稻組合之結實率則降低，如 $P_1 \times P_2$ 爲 71 % ， $P_2 \times P_1$ 爲 75 %，正反交間差異不大；異型品種間雜交 F_1 之結實率更行減低 ， 其變域在 58～82 %間，部分組合亦有正反交差異，除 $P_3 \times P_1$ 之結實率降低外 (68 %) ，其他三個以稉稻爲母本之雜交組合可增加結實率 ($P_3 \times P_2$=76 %；$P_4 \times P_2$=82 %；$P_4 \times P_3$=72 %) 。又水稻結實率之增進、如盧、孔[9] 所稱，行後代繼續選拔可具效果。

(六) 千粒重：秈稻品種之千粒重比稉稻品種低 2 ～ 3 克。同型品種間正反交無差異，異型品種間之部分雜交 F_1 超過親本，並且以稉稻爲母本者可增加千粒重，如 $P_3 \times P_2$ 爲 19 克、$P_4 \times P_2$ 爲 27 克、$P_4 \times P_1$ 爲 26 克等。

二、秈稉稻各雜交組合 ($\bar{F}_1$) 與親本間各數量性狀之顯性效果測驗

各雜交組合之 F_1 各性狀平均數 ($\bar{F}_1$) ，親本中間值 (MP) 及高親本平均數 ($\overline{HP}$) 或低親本平均數 ($\overline{LP}$) 比較測量之，測驗公式如下，其結果列於表 2 。

$$t = \frac{\bar{F}_1 - \overline{HP} \ (\text{or } \overline{LP})}{\sqrt{\frac{2}{n}\,(\text{MSE})}} \quad \text{and} \quad t = \frac{\bar{F}_1 - \text{MP}}{\sqrt{\frac{3}{2n}\,(\text{MSE})}}$$

n ：區集數

MSE：機差均方

表 2. 雜交組合與親本之差異顯著性測驗

Table 2. Tests of significance for differences between $\bar{F}_1$ hybrids and parents in a 4×4 diallel cross

Characters	Cross combination	$\bar{F}_1$	MP	$\overline{HP}$	$\overline{LP}$	$\bar{F}_1$-MP	$\bar{F}_1$-$\overline{HP}$	$\bar{F}_1$-$\overline{LP}$	Level of significance
Plant height (cm)	$P_1 \times P_2$	101.5	88.5	91	86	13**	10.5**	15.5**	$\bar{F}_1$-MP 5% 6.93
	$P_1 \times P_3$	107.5	98.5	106	91	9*	1.5	16.5**	1% 9.25
	$P_1 \times P_4$	106.5	95.5	102	91	10*	4.5	15.5**	
	$P_2 \times P_3$	109	96	106	86	13**	3	23**	
	$P_2 \times P_4$	114	94	102	86	20**	12**	28**	$\bar{F}_1$-$\overline{HP}$ 5% 7.94
	$P_3 \times P_4$	111	104	106	102	75*	5	9**	1% 10.6
Panicle number	$P_1 \times P_2$	15	13.5	14	13	1.5	1	2	$\bar{F}_1$-MP 5% 3.87
	$P_1 \times P_3$	15	11.5	14	9	3.5	1	6**	1% 6.16
	$P_1 \times P_4$	13	13.5	14	13	-0.5	-1	0	
	$P_2 \times P_3$	16	11	13	9	5*	3	7**	
	$P_2 \times P_4$	12	13	13	13	-1	-1	-1	$\bar{F}_1$-$\overline{HP}$ 5% 4.43
	$P_3 \times P_4$	11.5	11	13	9	0.5	-1.5	2.5	1% 6.92
Panicle length (cm)	$P_1 \times P_2$	24	22.5	23	22	1.5*	1	2**	$\bar{F}_1$-MP 5% 1.25
	$P_1 \times P_3$	25.5	21.5	22	21	4**	3.5**	4.5**	1% 1.67
	$P_1 \times P_4$	25.5	21.5	22	21	4**	3.5**	4.5**	
	$P_2 \times P_3$	25.5	22	23	21	3.5**	2.5**	4.5**	
	$P_2 \times P_4$	25	22	23	21	3**	2**	4**	$\bar{F}_1$-$\overline{HP}$ 5% 1.43
	$P_3 \times P_4$	22	21	21	21	1	1	1	1% 1.91
Number of spikelet per panicle	$P_1 \times P_2$	116	107.5	117	98	8.5	-1	18	$\bar{F}_1$-MP 5% 32.36
	$P_1 \times P_3$	137.5	114	117	111	23.5	20.5	26.5	1% 43.23
	$P_1 \times P_4$	138.5	118	119	117	20.5	19.5	21.5	
	$P_2 \times P_3$	136.5	104.5	111	98	32	25.5	38.5**	
	$P_2 \times P_4$	153	108.5	119	98	44.5**	34	55**	$\bar{F}_1$-$\overline{HP}$ 5% 37.12
	$P_3 \times P_4$	124.5	115	119	111	9.5	3.5	31.5	1% 49.58

續表2.

Characters	Cross combination	$\bar{F}_1$	MP	$\overline{HP}$	$\overline{LP}$	$\bar{F}_1$-MP	$\bar{F}_1$-$\overline{HP}$	$\bar{F}_1$-$\overline{LP}$	Level of significance
Seed fertility (%)	$P_1 \times P_2$	73	91.5	94	89	-18.5**	-21**	-16**	$\bar{F}_1$-MP 5% 6.83
	$P_1 \times P_3$	72	93.5	94	93	-21.5**	-22**	-23**	1% 9.12
	$P_1 \times P_4$	80.5	92.5	94	91	-12**	-13.5**	-10.5**	
	$P_2 \times P_3$	67	91	93	89	-24**	-26**	-22**	
	$P_2 \times P_4$	68	90	91	89	-22**	-23**	-21**	$\bar{F}_1$-$\overline{HP}$ 5% 7.81
	$P_3 \times P_4$	93	92	93	91	1	0	1	1% 10.44
1000-grain weight (g)	$P_1 \times P_2$	24	22.5	23	22	1.5*	1	2*	$\bar{F}_1$-MP 5% 1.51
	$P_1 \times P_3$	24	23.5	25	22	0.5	-1	2*	1% 2.02
	$P_1 \times P_4$	25.5	23.5	25	22	2*	-0.5	3.5**	
	$P_2 \times P_3$	27.5	24	25	23	3.5**	2.5**	4.5**	
	$P_2 \times P_4$	26.5	24	25	23	2.5**	1.5	3.5**	$\bar{F}_1$-$\overline{HP}$ 5% 1.75
	$P_3 \times P_4$	25.5	25	25	25	0.5	0.5	0.5	1% 2.34

由表 2 知，雜交組合 $P_1 \times P_2$ 及 $P_2 \times P_4$ 之株高；$P_1 \times P_3$、$P_1 \times P_4$、$P_2 \times P_3$ 及 $P_2 \times P_4$ 之穗長；$P_2 \times P_3$ 之千粒重等均超過高親本而達極顯著水準。結實率在高、中及低親本中均為負值。株高、穗長及千粒重之 $\bar{F}_1$ 均超過低親本或親本中間值而達顯著水準。因顯著性測定值是以正反交組合之平均值為準，在很多組合中因有正反交之差異，致使多數性狀 F_1 之平均值不能超過高親本，但實際上如表 1 所列，仍有部分正交或反交組合超過親本，如穗數之 $P_1 \times P_2$ 及 $P_3 \times P_2$（各為 18 支）、每穗粒數之 $P_2 \times P_4$ (172 粒) 及 $P_4 \times P_1$ (165 粒)、千粒重之 $P_3 \times P_2$ (29 克) 及 $P_4 \times P_2$ (27 克等)。

三、完全組合互交之變方分析

以單株資料為分析對象，重複四次，四個親本，先由一般變方分析估計處理、機差及總計等變因之平方和及均方，再以四重複之總數為分析對象，依據 Hayman 氏[11] 之公式估算各種遺傳變因之平方和及均方，茲將分析結果列於表 3。

表 3. 水稻全互交各性狀之變方分析表

Table 3. Analysis of variance of six agronomic traits of rice

Source of variation	df	Mean square					
		Plant height	Panicle number	Panicle length	Number of spikelet per panicle	Seed fertility	1000-grain-weight
Block	3	32.55	25.18	1.04	366.31	4.33	1.56
Treatment	15	598.38**	30.84**	18.45**	1532.72*	525.32**	11.73**
(a)	3	439.51**	26.3	10.29**	416.78	460.34**	14.97**
(b)	6	361.99**	22.49**	25.41**	2107.09*	917.22**	13.96**
(b_1)	1	1686.85**	32.51	86.67**	6244.92**	3061.61**	42**
(b_2)	3	104.05*	29.05*	0.76	404.36	329.84**	5.75*
(b_3)	2	86.47	7.65	31.75**	2592.25*	726.11**	12.26**
(c)	3	1708.73**	74.81**	19.28**	675.58	130.33**	8.98**
(d)	3	119.7*	9.1	11.86**	2356.08*	201.49**	6.79**
Error	45	31.04	9.63	1.01	681.43	30.18	1.49
Total	60						

* and ** : Significant at 5% and 1% level, respectively.

由表3各變因顯著性測驗結果，有下列幾點重要事實顯示：

(一) 株高、穗長、結實率及千粒重之a變因〔主要係由各親本間之遺傳變異所造成〕，其F值極大且達極顯著水準，表示四個親本間有極大的遺傳變異量存在，而穗數及一穗粒數則否。

(二) 各數量性狀之b變因〔係由於異質遺傳因子間的顯性效果 (dominant effect) 所造成〕，其F值均達極顯著程度，可知各種雜交組合間，有極明顯之顯性效果存在。

(三) b變因內含 b_1，b_2 及 b_3 變因。b_1 變因之F值，穗數不顯著，餘均達極顯著程度，表示平均顯性效果 (mean dominant effect) 有極明顯存在。b_2 變因僅在結實率之F值達極顯著程度，表示遺傳因子頻度 (Genes frequency) 不相等所造成之顯性變異有明顯差別。 b_3 變因在穗長、結實率及千粒重達極顯程度，表示某些親本間之雜交具有特殊雜交結合力 (Specific Combining ability) 存在。

(四) c及d二變因均屬於互交間之差異，c變因係以r個親本作父本與r個親本爲母本之差異所造成的變異，d變因係剩餘之各互交組合差異所造成之變異，由表知除穗數外，餘均達極顯著程度，表示組合間有互交差異存在。

四、水稻數量性狀之各種遺傳變方成分分析

由變方分析結果知，親本間之遺傳變異甚大，雜交組合間之顯性效果亦極顯著。再依據 Hayman 氏[12] 方法進行變方成分分析，茲將各種性狀之估計結果列如表4。

表 4. 水稻各種數量性狀之遺傳變方成分及各種估值

Table 4. Genetic components and ratios between components from a 4 × 4 diallel cross

Statistic	Plant height	Panicle number	Panicle length	Number of spikelet per panicle	Seed fertility	1000-grain weight
D	80.3±17.0	1.8±1.3	0.7±0.3	-78.0±114.0	-2.5±99.5	1.2±0.7
H_1	174.4±47.8	8.3±3.7	12.0±0.9	678.6±319.4	481.1±278.9	6.6±1.9
H_2	164.6±46.8	6.4±3.5	11.6±0.9	712.2±355.9	443.4±267.1	6.3±1.8
$\hat{E}$	7.7∓7.6	3.1±0.5	0.2±0.1	170.3±50.9	7.5±44.5	0.3±0.3
F	38.7±43.8	2.4±3.3	0.0±0.8	-79.3±292.9	-18.7±256.7	0.0±1.8
h^2	311.1±31.0	3.8±2.3	17.5±0.6	1041.9±207.5	570.4±181.1	8.6±1.2
$D-H_1$	-94.1±44.7	-6.4±3.4	-11.3±0.8	-756.6±298.4	-483.6±44.5	-5.4±1.8
$(H_1/D)^{\frac{1}{2}}$	1.4	2.1	4.1	—	—	2.3
$\overline{uv}=\frac{H_2}{4H_1}$	0.2	0.1	0.2	0.2	0.2	0.2
$\frac{h^2}{H_2}$	1.8	0.5	1.5	1.4	1.2	1.3
K_D/K_R	1.3	1.9	1	—	—	1

$D=\sum di^2\ (1-wi^2)$　　di：表遺傳因子之累加性效果

$F=2\sum dihiwi\ (1-wi^2)$　　wi：爲遺傳因子頻度不相等之差異平均值 ($wi=ui-vi$)

$H_1=\sum hi^2\ (1-wi^2)$　　hi：表遺傳因子之顯性效果

$H_2=\sum hi^2\ (1-wi^2)^2$

$h^2=\sum hi\ (1-wi^2)$　　—：因D爲負值

$E=MSE/n$

由表 4 知，各種數量性狀之 H_1 大於 D，表示遺傳因子之顯性變方大於累加性變方 。$\overline{uv}=H_2/4H_1$ 表遺傳因子頻度，因各性狀間之 H_1 與 H_2 均有差別，即某一個因子座中之正相對因子與負

相對因子之比例在親本中不相等。 $K_D/K_R = \frac{(4DH_1)^{\frac{1}{2}} + F\text{（顯性因子總數）}}{(4DH_1)^{\frac{1}{2}} - F\text{（隱性因子總數）}}$ 表顯隱性因子數之比值，除每穗粒數及結實率外，其他各性狀間均有不同差別，且大於 1，表示顯性因子數較大。H_1/D 表顯性程度、株高、穗數、穗長及千粒重等數量因子之顯性程度均大於 1，表示爲完全顯性或超顯性。

理論上，遺傳組成分之估值，除 F 外，其他估值，如 D、H_1、H_2 及 h^2 不得爲負值[3]，但在本例中之 D，每穗粒數及結實率爲負值，其原因是親本間差異不大， 區集內差異太大，以致機差過大，或是所用材料之遺傳行爲與 Hayman 氏分析法的假設不符合（如 Hayman 氏之諸假設中即有一爲正反交無差異），因此 $D = VP - MSE/n$ 爲負值；又如表 4 各性狀之顯性遺傳變方大於累加性遺傳變方，表示本研究之六個數量性狀，均不容易迅速選出優良品系，必須到後世代中才有可能表現出優異的性狀。

參考文獻

1. 邱再發、連深、徐水泉・ 1961・臺灣水稻之養分吸收之研究 第 2 報日本型及印度型水稻之養分吸收與溫度之關係・農業研究 10(1)： 7-20。
2. 林安秋、陳建山・1977・第二期稻作低產原因之研究 3・不同溫度持續對水稻之分蘖及光合作用能力之影響・中華農學會會報新 (98)：55-60。
3. 湯文通・1967・作物育種之原理與實施：162-197。
4. 張德梅・1970・半矮稻遺傳之研究・農業研究 19(4)：1-10。
6. 張德梅・1971・水稻數量性狀遺傳之研究 I．半矮稻品種間之全互交・農業研究 20(2)：9-26。
6. 張恩雨・1963・菸草黃色種柏萊種及土耳其種品種間之完全組合互交・中華農學會報新 (44):18-27。
7. 賴光隆、侯清利・1974・關於稻根生理、生態之研究——異型間稻根呼吸特性的比較與應用・ 國立臺灣大學農學院研究報告 15：13-27。
8. 簡錦忠・1978・臺灣一、二期稻病害發生情形及其對產量之影響・ 載於臺灣二期作稻低產原因及其解決方法之研討會專集 行政院國家科學委員會研討會專集（二）：179-189。
9. 盧守耕、孔德諟・1963・粳秈稻雜種後代稔實率及若干農藝性狀個體選拔效果之研究・ 中華農學會報新 (42)：1-12。
10. Chang, T. T., C. C. Li and O. Taqumay. 1973. Genotypic correlation, heterosis, depression and transgressive segregation of agronomic traits in a diallel cross of rice (*Oryza sativa* L.) cultivars. Bot. Bull. Acad. Sinica 14 : 83-93.
11. Hayman, B. I. 1954a. The analysis of variance of diallel tables. Biometerics 10 : 235-244.
12. Hayman, B. I. 1954b. The theory and analysis of diallel crosses. Genetics 39 : 789-809.
13. Kato, S, H. Kosaka, S. Hara, Y. Maruyama and Y. Takigusi. 1930. On the affinity of the cultivated varieties of rice plants. *Oryz a sativa* L. J. Dep. Agr., Kyushu Imp. Univ. 2 : 241-276.
14. Li, C. C. and T. T. Chang. 1970. Diallel analysis of agronomic traits in rice (*Oryza sativa* L.). Bot. Bull. Acad. Sinica 11 : 61-78.
15. Li, C. C. 1975. Diallel analysis of yield and its components traits in rice (*Oryza sativa* L.). Jour. Agri. Assoc. 92 : 41-56.
16. Wu, H. P. 1968. Studies on the quantitative inheritance of *Oryza sativa* L. I. and II. Bot. Bull. Acad. Sinica 9 : 1-9, 124-138.

Studies on the quantitative inheritance of rice (*Oryza sativa* L.)

II. Diallel cross of *Japonica* and *Indica* varieties [1]

Te-Mei Chang [2]

Summary

Two *indica* varieties (P_1 = Chianung sen No. 11, P_2 = Taichung Native No. 1) and two *japonica* varieties (P_3=Tainan No. 5, P_4=Tainung 67) were used as materials in this experiment. Crosses were made between these varieties in accordance with a diallel scheme, including reciprocals and selfing. The purpose was to study the genetic behavior of several important quantitative characters. The results were summarized as follows:

1. The four parents differed significantly in the agronomic characters of plant height, panicle length, seed fertility rate and 1000-grain weight. Dominance effect in these characters was observed in the F_1 progenies. Significant differences were also observed among diallel crosses.

2. Dominant variance (H_1) for various characters was greater than additive genetic variance (D). The values of $(H_1/D)^{\frac{1}{2}}$, an expression of degree of dominance, was larger than 1 for many characters investigated except fertility rate and number of spikelet per panicle, suggesting total dominance or over-dominance. For plant height, panicle number, spikelet number and fertility rate, $H_1 \neq H_2$, i. e., $u \neq v$, was recorded, indicating the dominance for these characters was partially contributed by the unequal frequencies of dominant and recessive genes. As K_D/K_R equals to 1 for panicle length and 1000- grain-weight, an equal number of dominant and recessive genes was therefore possible. Results of h^2/H_2 indicated that the degree of dominance was controlled by 1-2 pairs of dominant genes for all the characters studied.

3. Seed fertility rate of F_1 progenies from crosses between *indica* and *japonica* varieties ranged from 58-82% and could be further increased if selections were made in later generations. The other three yield components, panicle number, number of spikelet per panicle and 1000-grain-weight, of F_1's had also been found to be superior to parents in many cases. It is therefore possible to breed new rice varieties through the crosses between *indica* and *japouica* varieties in the future.

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生長素對早熟稻產量及產量構成因素之影響[1]

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摘要：以早熟稻品種日本晴 (Nipponbare)，廣陸矮 4 號 (Kwang-lu-ai 4) 及本地現行栽培品種臺農 67 號 (Tainung 67) 爲材料，於 1978 年 1、2 期作種植於田間。在分蘖期始期及分蘖盛期施用 Chloroflurenol (IT3456, methyl-2-Chloro-9-hydroxy-fluroene-(9)-carboxylate) 1 mM，並於幼穗分化期、孕穗期及乳熟期加施 50 ppm 之 SNA (sodium naphthalene acetic acid) 與 2000 倍稀釋液之 SNP (sodium nitrophenol) 之混合液，以及 50 ppm 之 GA_3 (gibberellin)，調查其對稻作生育之反應及對產量之影響。試驗結果摘要如下：(1)施用 Chloroflurenol 對分蘖數之增加有顯著之效果(1 期作增加 3～12 %，2 期作增加 9～19%)，但所增加之分蘖大部份爲無效分蘖，且由於分蘖數之增加會導致一穗平均粒數及千粒重之降低。(2)生育後期加施 SNA 與 SNP 混合液可使增加之無效分蘖成爲有效分蘖，一株穗數、發育穎花數、結實率及千粒重亦增加，因而使產量增加 4～11 % (1 期作) 及 5～14 % (2 期作)。(3)加施 GA_3 對株高、穗長及粒長有顯著影響外，對其他農藝性狀效果不穩定。(4)三供試品種間，以臺農 67 號對不同生長素處理有較好之反應；稉型早熟品種日本晴因施用 Chloroflurenol 而促進之分蘖數增加效果最大；秈型早熟品種廣陸矮 4 號對上述生長素處理，則在一株穗數、千粒重及株高方面較其他供試品種增加效果大。

近年來，政府爲了調節稻米生產，乃積極推行早熟稻栽培，因爲栽植早熟稻，生育日數縮短，有利於三期稻作或輪作之實施，在平時糧食不虞匱乏時，實行水稻與其他作物輪作，以增加雜糧之生產，而於糧食不足時，則行三期稻作，如此可以機動調節稻米生產，並可減少由國外進口雜糧之依賴；且栽種耐寒早穫稻，南部第一期作或北部第二期作可提早收穫，以逃避梅雨或季節風以及病蟲害之爲害，間接提高稻米生產。早熟稻品種之生育日數一般較本省栽培品種縮短 20～25 天，然而亦由於其基本營養期較短，單位面積平均產量要較一般栽培種減少 6～15 % [6]，因此，爲了要提高早熟稻產量，必須由栽培法及品種改良著手。品種改良雖是可行且爲一勞永逸的辦法，但需要長期的時間，且不一定保證能完全解決問題；反之，栽培法便成爲一個短期目標的工作，例如半矮型 (semi-dwarf) 品種之應用 [13]，「V」字型施肥法 [12]，以及葉面施用尿素或生長調節素 (growth regulator) [1,2,3] 等，均可以使產量提高。

作物之生長發育單靠肥料外，尚需要 CO_2、光線，同時還要充足之荷爾蒙始能相輔相成 [14]，目前已知多種植物生長素對植物形態發生作用 [11,14,15]，其對植物之作用是多方面而極爲複雜。本試驗所使用之生長調節素包括 Chloroflurenol (IT 3456, methyl-2-chloro-9-hydroxy-fluroene-9-carboxylate), SNA (sodium naphthalene acetic acid), SNP (sodium nitrophenol) 及 GA_3 (gibberellin)。Chloroflurenol 爲一種 auxin 運移抑制劑 (auxin transport inhibitor)，能抑制某些植物的頂芽優勢 (apical dominance)，導致側芽生長 [10,16]；SNA 亦爲人工合成之生長

1. 臺灣省農業試驗所 研究報告 第 921 號。本研究爲第一作者碩士論文之部份，蒙黃眞生博士、臺大農藝系朱鈞教授指導，文承劉大江博士斧正，謹此申謝。

2. 本所農藝系技佐、技正。臺灣省 臺中縣 霧峰鄉。

調節素，已被廣泛用於作物之生長調節，諸如開花之控制，揷枝之生根等[3]；SNP 則爲市面上可購得之所謂「果多生長素」，商品名爲「利多生」或「愛多收」，對穎花之分化、生長及結實率、千粒重有促進作用[3]； GA_3 對植物生長之影響，最明顯者即是引起株高、葉長、葉寬顯著增加[8,17]，亦能影響開花及結果[15]。

稻米之生產力受一株穗數、一穗粒數、結實率及千粒重之影響，而單位面積穗數爲決定產量之主要因素之一[5]，穗數受有效分蘗之影響，分蘗數除生育環境，營養狀況外，生長調節素亦具有影響力。生長調節素亦影響水稻之花穗發育，從而影響每穗穎花數及千粒重，因此，如能適時施用對水稻分蘗及穎花發育有效之生長調節素，使其生長受到良好調節，再行適當施肥，必有助於稻米產量之提高。本試驗即在於探討生長調節素對水稻產量構成因素之主要影響，期能有助於日後施用生長素以提高產量之參考。

材料與方法

本試驗供試水稻品種爲引進之日本耐寒早熟水稻—日本晴(Nipponbare)、廣陸矮 4 號(Kwang-lu-ai 4)，並以本地優良品種臺農 67號 (Tainung 67) 爲對照品種，於民國 67 年一、二期作種植於臺灣大學農業試驗場。田間設計採用一重裂區設計 (one-fold split plot design)，三個品種 (V_1, V_2, V_3) 及四種生長素處理 (T_1, T_2, T_3, T_4)，生長素處理爲主試因，品種爲副試因，主處理之排列方式採逢機完全區集設計 (ramdomized complete block design)，每小區爲 100 株，單本植，行株距爲 25×20 cm，重複四次，其施肥法、施肥量、灌漑排水及田間管理沿用一般慣用法，並適時施用殺草劑、殺菌蟲劑行病蟲害及雜草之防除。

移植後於分蘗開始期及分蘗盛期，全部施用 Chloroflurenol，然後於幼穗分化期 (穗長約 1～2 mm)，孕穗期及乳熟期時分別施用 SNA 與 SNP 之混合液或 GA_3，施用法爲噴施藥液於葉面，至葉面有小水滴滴下爲止，藥液濃度爲 Chloroflurenol 1mM, SNA 50 ppm, SNP 2,000 倍稀釋液， GA_3 50 ppm。各處理代號如下所示：

T_1 : CK	V_1 : 臺農 67 號 (Tainung 67)
T_2 : Chloroflurenol	V_2 : 日本晴 (Nipponbare)
T_3 : Chloroflurenol, SNA+SNP	V_3 : 廣陸矮 4 號 (Kwang-lu-ai 4)
T_4 : Chloroflurenol, GA_3	

移植後每 10 天以每小區固定中間 10 株調查其分蘗數，第 40 天及成熟後調查株高、抽穗期及成熟期；於水稻完熟後，自每小區中逢機割取 5 株晾乾考種，考種項目包括一株穗數、穗長、穗重、一穗平均粒數、一株總粒數、結實率、千粒重、粒幅、粒長。另外並於乳熟期時，自每小區中逢機選取 5 株，每株取具代表性者 3 穗調查退化枝梗數，一次、二次枝梗退化穎花數，一次、二次枝梗發育穎花數。成熟後，每小區並分別割取稻穀、晒乾、風選及秤重。其各農藝性狀及稻穀產量之調查及考種方法均和一般水稻試驗同。

試驗結果

一、一期作試驗之結果

一期作施用不同生長素對農藝性狀、產量成分及產量之影響，結果如下：

(一) 株高：各種生長素處理對株高之影響，於移植後 40 天調查結果，前期施用 Chloroflurenol 之 T_2、T_3 及 T_4 處理，有使株高下降之趨勢，但不顯著。成熟後之株高，則處理間、品種間及兩者之交感均極顯著 (表 2)，以施用 GA_3 之 T_4 處理較其他處理者高，尤以日本晴及廣陸矮 4 號最爲顯著 (表 1)。

(二) 分蘗數：各種生長素處理對稻株分蘗數之影響如圖 1 所示，於生育前期分蘗數無大差異

，但於第二次施用 Chloroflurenol 後之 T_2、T_3 及 T_4 處理之分蘖數較之未施用 Chloroflurenol 之 T_1 對照處理分蘖數明顯提高。其最高分蘖數的處理間及品種間差異均顯著（表 2），尤以臺農 67 號及日本晴兩品種施用 Chloroflurenol 較未施用者，其最高分蘖數顯著提高（表 1）。

（三）一株穗數：施用 Chloroflurenol 之 T_2、T_3 及 T_4 處理之穗數均較未處理者稍大，然以臺農 67 號及日本晴施用 SNA+SNP 混合液之 T_3 處理對穗數之增加有顯著之效果，廣陸矮 4 號則無此效應（表1）。

（四）生育日數：臺農 67 號及日本晴品種，施用生長素者較未施用者生育日數縮短 1～3 天，而施用 GA_3 者，可使其生育日數縮短 3 天（表 1）。

（五）粒幅：三品種間之粒幅差異極顯著，其他變因均不顯著（表 2），但施用 SNA+SNPG 之 A_3 處理，有使粒幅較大之效應，施用 GA_3 者亦使臺農 67 號之粒幅較大，但對於早熟稻日本晴及廣陸矮 4 號之粒幅，較之未施用 GA_3 者有下降之效應，唯其差異均不顯著（表 1）。

（六）粒長：處理間及品種間之差異均不顯著（表 1.2）。

（七）穗長：處理間差異顯著（表 2），其中以施用 SNA+SNP 及施用 GA_3 處理者，在三品種中均使其穗長增加，尤以 GA_3 處理更爲顯著（表 1）。

（八）穗重：品種間差異顯著（表 2），以臺農 67 號穗重最大，日本晴次之，而施用 SNA+SNP 之處理亦有使穗重增加之效果，但並不顯著（表 1）。

（九）一穗平均粒數：品種間差異顯著（表 2），施用 Chloroflurenol 之 T_2 處理，較未施用之 T_1 處理之一穗平均粒數稍低，而其他處理間之差異並不顯著（表 1）。T_1 處理有使一穗穎花數增加之效果，主要由於退化穎花數減少及發育穎花數增加，尤其是發育二次穎花顯著增加之關係（表 3）。

（十）一株總粒數：處理間、品種間差異均顯著（表 2），T_3、T_4 處理對於各品種一株總粒數有增加之效果（表 1）。

（十一）結實率：品種間差異顯著（表 2），T_2 及 T_3 處理之結實率較 T_1 處理有增加趨勢，但 T_4 處理却使臺農 67 號及廣陸矮 4 號之結實率稍降，然均不顯著（表 1）。

（十二）千粒重：品種間差異顯著（表 2）。T_2、T_3 及 T_4 處理其千粒重較 T_1 處理有下降之趨勢，而廣陸矮 4 號之 T_3 處理却有增加之效果（表 1）。

（十三）產量：各處理組合之穀粒產量經變方分析結果，品種間產量差異極顯著，處理間差異不顯著，但 F 值甚接近顯著水準（表 7）。品種間以臺農 67 號產量最高，日本晴最低；各處理間以最低差異顯著性測驗結果，則加施 SNA+SNP 之 T_3 處理有顯著的增產效果（表 1）。

二、二期作試驗之結果

二期作施用不同生長素對農藝性狀、產量構成因素及產量之影響，結果如下：

（一）株高：前期施用 Chloroflurenol 之 T_2、T_3 及 T_4 處理，於移植後 40 天調查株高結果有下降之趨勢，但不顯著；成熟期之株高，處理間及品種間均呈顯著差異，區集間之差異亦顯著（表 5），處理間以 T_4 處理有極顯著之增高效果（表 4）。

（二）分蘖數：如圖 2 所示，日本晴及廣陸矮 4 號於移植後30天，分蘖數即達最高，且三品種在第一次施用 Chloroflurenol 後之 T_2、T_3 及 T_4 處理之分蘖數較之未施用 Chloroflurenol 之 T_1 對照處理漸趨增加，各處理之最高分蘖數，經變方分析結果，處理間及品種間之差異均極顯著（表 5）。

（三）一株穗數：處理間與品種間差異均極顯著（表 5）。以前期施用 Chloroflurenol，後期再加施 SNA+SNP 混合液之 T_3 處理，對各品種穗數之提高有極顯著之效果（表 4）。

（四）生育日數：三品種施用不同生長素處理較之未施用之 T_1 處理，均可使其生育日數短縮 1～3 天。早熟稻品種日本晴及廣陸矮 4 號較之臺農 67 號早熟 16～21 天（表 4）。

表 1. 不同生長素處理組合間主要農藝性狀之最低差異顯著性（L.S.D.）測驗（I 期作）

Table 1. The L. S. D. test of the agronomic characters among different treatments. (1st crop)

品種 Var.	處理 Treat.	最高分蘗數 Max. tiller no.	株高 Plant height (cm)	穗數 Panicle no.	生育日數 Growth days	粒幅 Grain width (mm)	粒長 Garin length (mm)	穗長 Panicle length (cm)	穗重 Panicle wt. (g)	一穗粒數 Grain/panicle	一株粒數 Grain/plant	結實率 Seedset (%)	千粒重 1000 grain wt. (g)	產量 Grain yield (kg/ha)
V_1	T_1	20.1 d*	106.5 a	16.9 d	140	3.31 bc	7.05 a	19.9 bc	2.04 a	102.1 a	1719 b	71.3 b	21.3 cd	4025 b
	T_2	22.5 c	105.2 a	17.8 d	139	3.34 bc	7.03 a	20.5 ab	2.03 a	96.0 b	1710 b	71.9 b	20.8 de	4067 b
	T_3	22.5 c	103.2 a	19.2 c	139	3.42 ab	7.15 a	21.0 a	2.08 a	101.2 a	1947 b	73.2 b	21.2 cde	4476 a
	T_4	21.5 c	107.4 a	17.8 d	137	3.46 a	7.04 a	21.2 a	2.03 a	101.1 ab	1789 b	69.9 b	20.7 e	4077 b
V_2	T_1	25.8 b	81.0 c	22.7 b	113	3.14 e	7.22 a	18.4 d	1.45 b	59.4 bd	1344 c	59.8 c	22.7 a	3396 d
	T_2	28.3 a	84.3 c	22.8 ab	113	3.19 de	7.12 a	18.2 de	1.47 b	59.1 de	1349 c	63.5 c	22.1 ab	3427 d
	T_3	28.1 a	83.4 c	23.7 a	112	3.20 de	7.22 a	19.4 c	1.52 b	59.4 de	1406 c	62.8 c	22.1 ab	3514 cd
	T_4	27.8 a	91.3 b	23.8 a	110	3.16 e	7.10 a	20.4 ab	1.44 b	57.2 e	1359 c	61.4 c	20.7 bcd	3478 cd
V_3	T_1	17.3 e	55.5 e	15.6 e	103	3.19 de	7.15 a	15.6 fg	1.21 c	62.4 cde	972 d	82.4 a	21.9 abc	3836 bc
	T_2	17.8 e	55.7 e	15.6 e	104	3.18 de	7.10 a	15.2 g	1.19 c	61.7 cde	958 d	82.6 a	21.2 cde	3832 bc
	T_3	17.8 e	53.5 e	15.6 e	104	3.24 de	7.14 a	16.4 f	1.22 c	62.9 cd	985 d	83.2 a	22.2 ab	4102 b
	T_4	17.7 e	73.1 d	16.5 e	100	3.13 e	7.20 a	17.4 e	1.19 c	65.8 c	1018 d	81.2 a	21.1 e	3608 bc

V_1 : Tainung 67
V_2 : Nipponbare
V_3 : Kwang-lu-ai 4

T_1 : CK
T_2 : Chlorflurenol
T_3 : Chlorflurenol, SNA+SNP
T_4 : Chlorflurenol, GA_3

*a, b, c, d. Any two means having a common letter are not significant at 5% level.

表 2. 不同生長素及品種處理組合間主要農藝性狀及產量構成要素之變方分析均方顯著性測驗（I 期作）

Table 2. ANOVA of agronomic characters and yield components among different treatments. (1st crop)

變因 S. O. V.	自由度 D. F.	株高 Plant height	最高分蘗數 Max. tiller no.	穗長 Panicle length	穗重 Panicle wt.	粒幅 Grain width	粒長 Grain length	產量構成要素 Yield component					產量 Grain yield
								一株穗數 Panicle/plant	一穗粒數 Grain/panicle	一株粒數 Grain/plant	結實率 Seedset	千粒重 1000 grain wt.	
區集 B	3	9.187	0.508	0.021	0.005	0.020	0.069	0.208	11.418	9453.667	7.708	1.399	88504.796
處理 T	3	277.596**	8.136**	8.124**	0.007	0.012	0.017	2.912*	14.811	44337.333**	14.450	1.702	204849.460
主區機差 Ea	9	12.479	0.335	0.389	0.009	0.006	0.040	0.431	24.470	12533.148	10.743	0.739	56506.129
品種 V	2	8537.091**	392.237**	82.907	2.993**	0.226**	0.039	247.091**	8146.844**	2741312.512**	1681.738**	5.535**	2050816.900**
處理×品種 T×V	6	74.132**	1.141	0.510	0.001	0.010	0.009	1.168	15.773	11867.535	3.255	0.261	31075.992
副區機差 Eb	24	7.100	0.532	0.347	0.010	0.006	0.038	0.485	12.975	9630.417	15.948	0.346	64048.481
總計 Total	47	—	—	—	—	—	—	—	—	—	—	—	—

表 3. 不同生長素處理對稻穗退化枝梗、退化穎花數、發育穎花數之影響（I期作）

Table 3. The influence of different treatments on the degenerated branch of panicle, degenerated spikelet and developed spikelet. (1st crop)

品種[a] Var.	處理[a] Treat.	退化枝梗數 Degenerated branch		退化穎花數 Degenerated spikelet		發育穎花數 Developed spikelet		一穗穎花數 Spikelet/panicle
		二次 Secondary	計 Total	二次 Secondary[b]	計 Total[c]	二次 Secondary[b] [d]	計 Total[c]	[d]
V1	T1	10.3	10.6	3.9(42.4)	9.2 〔7.3〕	57.0(49.0) bc	116.4 b 〔92.7〕	125.6 b
	T2	11.9	12.4	5.4(46.6)	11.6 〔9.6〕	50.6(46.0) cd	109.8 b 〔90.4〕	121.4 b
	T3	9.2	9.4	2.4(42.1)	5.7 〔3.9〕	75.4(53.9) a	139.8 a 〔96.1〕	145.5 a
	T4	13.8	14.0	6.9(58.0)	11.9 〔8.3〕	64.9(49.5) c	131.8 a 〔91.7〕	143.7 a
V2	T1	2.7	3.1	1.0(40.0)	2.5 〔3.5〕	35.2(51.1) ab	68.9 e 〔96.5〕	71.7 e
	T2	2.9	2.9	2.2(51.2)	4.3 〔6.0〕	33.5(49.6) b	67.5 e 〔94.0〕	71.8 e
	T3	2.7	2.7	0.9(40.9)	2.2 〔2.5〕	45.8(53.4) a	85.7 c 〔97.5〕	87.9 e
	T4	4.0	4.1	3.3(60.0)	6.5 〔6.6〕	39.6(50.9) ab	77.8 cd 〔93.4〕	83.3 cd
V3	T1	2.5	2.6	2.8(65.1)	4.3 〔5.6〕	31.9(44.5) d	71.8 ed 〔94.4〕	76.1 de
	T2	2.8	3.0	3.4(77.3)	4.4 〔5.8〕	31.8(44.9) d	70.9 ed 〔94.2〕	75.3 de
	T3	2.0	2.0	2.0(76.9)	2.6 〔3.2〕	39.6(50.0) b	79.2 cd 〔96.8〕	81.8 cd
	T4	2.4	2.5	3.1(60.8)	5.1 〔6.6〕	35.0(48.9) bc	71.7 de 〔93.4〕	76.8 de

a. 品種及處理代號如表1所示。
Varieties and treatments refer to Table 1.

b. (　) 內表示佔該項小計之百分率。
Indicate % to total degenerated or developed spikelet.

c. 〔　〕內表示佔總計之百分率。 Indicate % to spikelet/panicle.

d. 同一字母表示5% level 下差異不顯著。 The same letter means not significant at 5% level.

表 4. 不同生長素處理組合間主要農藝性狀之最低差異顯著性（L.S.D.）測驗（II期作）

Table 4. The L. S. D. test of the agronomic characters among different treatments. (2nd crop)

品種[a] Var.	處理[a] Treat.	最高分蘗數 Max. tiller no.	株高 Plant height (cm)	穗數 Panicle no.	生育日數 Growth days	粒幅 Grain width (mm)	粒長 Grain length (mm)	穗長 Panicle length (cm)	穗重 Panicle wt. (g)	一穗粒數 Grain/Plant	一株粒數 Grain/plant	結實率 Seed set (%)	千粒重 1000 grain wt. (g)	產量 Grain yield (kg/ha)
V_1	T_1	16.7 d[b]	105.0 b	14.5 e	126	3.05 ed	6.14 b	20.3 b	1.40 a	96.4 a	1391 c	68.8 bc	21.1 abc	3300 bc
	T_2	19.8 c	104.6 b	14.5 e	125	3.14 abc	6.28 b	20.2 b	1.37 a	96.3 a	1397 c	69.6 bc	20.8 bc	3250 bcd
	T_3	20.2 c	100.8 bc	17.3 c	126	3.09 cd	6.19 b	20.4 b	1.48 a	98.7 a	1703 a	71.3 bc	21.1 abc	3745 a
	T_4	20.1 c	114.9 a	15.0 de	124	3.18 abc	6.35 b	22.0 a	1.38 a	98.1 a	1467 b	70.1 bc	20.5 cd	3240 bcde
V_2	T_1	20.8 c	75.2 e	19.2 b	95	2.91 f	7.15 a	16.6 h	0.83 d	61.7 c	1179 d	58.7 e	21.3 abc	2998 def
	T_2	24.2 a	72.0 e	19.5 ab	94	2.91 f	7.25 a	16.7 gh	0.83 d	61.2 c	1196 d	60.1 e	21.1 abc	2990 ef
	T_3	24.8 a	71.9 e	20.6 a	94	2.98 ef	7.30 a	17.5 fg	0.88 cd	60.9 c	1255 cd	64.8 cde	22.0 a	3156 cdef
	T_4	25.0 a	87.4 d	19.3 ab	92	2.96 f	7.36 a	18.6 cd	0.83 d	60.6 c	1172 de	62.1 de	20.3 cd	2908 f
V_3	T_1	21.0 bc	77.5 e	13.6 e	100	3.22 abc	7.26 a	16.9 gh	0.95 bc	73.8 b	1003 f	69.3 bc	20.9 bc	3103 cdef
	T_2	23.1 ab	77.2 e	14.1 e	99	3.17 abc	7.27 a	17.7 ef	0.99 b	72.8 b	1024 df	67.2 bcd	21.5 abc	3174 bcde
	T_3	23.5 a	77.1 e	16.0 cd	99	3.22 a	7.25 a	18.2 de	1.06 b	73.0 b	1164 de	77.5 a	21.7 ab	3389 b
	T_4	24.3 a	96.6 c	13.8 e	97	3.12 bcd	7.39 a	19.1 c	0.95 bc	70.5 b	967 f	71.8 ab	19.6 d	3035 df

a. 品種及處理代號如表 1 所示。Varieties and treatments refer to table 1.

b. 同一字母表示 5 % level 下差異不顯著。The same letter means not significant at 5% level.

表 5. 不同生長素及品種處理組合間主要農藝性狀及產量構成要素之變方分析均方顯著性測驗（II 期作）

Table 5. ANOVA of agronomic characters and yield components among different treatments. (2nd crop)

變因 S. O. V.	自由度 D. F.	株高 Plant height	最高分蘗數 Max. tiller no.	穗長 Panicle length	穗重 Panicle wt.	粒幅 Grain width	粒長 Grain length	產量構成要素 Yield component					產量 Grain Yield
								一株穗數 Panicle/plant	一穗粒數 Grain/Panicle	一株粒數 Grain/plant	結實率 Seedset	千粒重 1000 grain wt.	
區集 B	3	26.026*	2.240	0.620	0.047*	0.001	0.055	0.607	68.161**	31110.667	47.452	0.549	5026.403
處理 T	3	1020.689**	33.512**	9.519**	0.020	0.004	0.057	12.322**	3.173	92390.654**	84.150*	4.167**	320661.700**
主區機差 Ea	9	4.351	2.474	0.081	0.009	0.010	0.027	0.342	7.162	5321.343	19.483	0.482	6975.177
品種 V	6	4801.951**	93.539**	51.514**	1.393**	0.247**	5.210**	128.211**	5506.824**	827221.156**	468.205**	0.384	553560.550**
處理×品種 T×V	2	17.456	0.670	0.309	0.002	0.013	0.035	0.601	5.975	14680.167	13.891	0.735	25729.097
副區機差 Eb	24	16.454	1.985	0.347	0.007	0.004	0.036	0.897	23.177	1094.917	18.637	0.525	18693.402
總計 Total	47	—	—	—	—	—	—	—	—	—	—	—	—

表 6. 不同生長素處理對稻穗退化枝梗、退化穎花數、發育穎花數之影響(Ⅱ期作)

Table 6. The influence of different treatments on the degenerated branch of panicle, degenerated spikelet and developed spikelet. (2nd crop)

品種[a] Var.	處理[a] Treat.	退化枝梗數 Degenerated branch: 二次 Secondary	退化枝梗數 Degenerated branch: 計 Total	退化穎花數 Degenerated spikelet: 二次 Secondary[b]	退化穎花數 Degenerated spikelet: 計 Total[c]	發育穎花數 Developed spikelet: 二次 Secondary[b][d]	發育穎花數 Developed spikelet: 計 Total[c]	一穗穎花數 Spikelet/panicle[d]
V1	T1	4.0	4.5	2.2(51.2)	4.3 〔4.9〕	48.9(45.6) ab	107.2 b 〔96.1〕	111.5 bc
	T2	4.3	4.7	2.1(44.7)	4.7 〔4.3〕	46.5(44.6) abc	104.2 b 〔95.7〕	108.9 bc
	T3	4.5	4.8	1.0(32.3)	3.1 〔2.4〕	57.5(47.6) a	120.7 a 〔97.6〕	123.7 a
	T4	3.8	4.1	2.5(58.1)	4.3 〔3.8〕	51.8(47.4) a	109.3 b 〔96.2〕	113.6 b
V2	T1	1.5	2.1	2.0(52.6)	3.8 〔5.1〕	29.3(42.7) bc	68.6 ef 〔94.9〕	72.3 g
	T2	1.8	2.2	3.2(57.1)	5.6 〔9.4〕	27.3(40.9) c	66.7 f 〔90.6〕	73.6 fg
	T3	1.6	3.9	2.9(65.9)	4.4 〔5.3〕	36.2(46.2) ab	78.4 d 〔94.7〕	82.8 ef
	T4	1.2	1.8	2.6(57.8)	4.5 〔6.2〕	27.6(41.3) c	66.8 f 〔93.8〕	71.2 g
V3	T1	4.4	5.3	3.6(29.3)	12.3 〔13.4〕	24.9(31.3) de	79.6 d 〔86.6〕	91.9 de
	T2	4.5	5.4	6.0(36.4)	16.5 〔17.8〕	21.1(27.7) e	76.3 de 〔82.2〕	92.8 d
	T3	6.2	6.9	5.1(44.0)	11.6 〔11.2〕	32.3(35.2) d	91.8 c 〔88.8〕	103.4 cd
	T4	5.4	2.5	3.7(32.5)	11.4 〔12.3〕	26.1(32.1) de	81.3 d 〔87.7〕	92.7 d

a. 品種及處理代號如表1所示。 Varieties and treatments refer to Table 1.
b. (　) 內表示佔該項小計之百分率。 Indicate % to **total** degenerated or developed spikelet.
c. 〔　〕內表示佔總計之百分率。 Indicate % to spikelet/panicle.
d. 同一字母表示 5% level 下差異不顯著。 The same letter means not significant at 5% level.

（五）粒幅：三品種間差異極顯著，其他變因則不顯著（表 5）。 T_3 處理能使粒幅增加，而 T_2 及 T_4 處理亦使臺農 67 號及日本晴品種之粒幅增大，但對廣陸矮 4 號則減小，唯其差異並不顯著（表 4）。

（六）粒長：除品種間差異極顯著外，其他變因均不顯著（表 5）， T_2 及 T_4 處理有使粒長增加之趨勢，但並不顯著，而施用 SNA+SNP 之 T_3 處理較之未施用 SNA+SNP 之 T_2 處理，却有使臺農 67 號及廣陸矮 4 號穀粒變短之效果，品種間以早熟稻品種日本晴及廣陸矮 4 號之穀粒長度大於臺農 67 號（表 4）。

（七）穗長：施用生長素之 T_2、T_3 及 T_4 處理均有增加穗長之效果，尤以施用 GA_3 之 T_4 處理效果最爲顯著（表 4）。

（八）穗重：施用 SNA+SNP 之 T_3 處理使三品種之穗重增加，而品種間以臺農 67 號最大，廣陸矮 4 號次之（表 4），區集間差異亦顯著（表 5）。

（九）一穗平均粒數：處理間差異不顯著，品種間有顯著之差異存在（表 5），以臺農 67 號爲最高，廣陸矮 4 號次之（表 4）。 T_3 處理有增加一穗穎花數之效果，主要乃由於發育穎花數之增加所致（表 6）。

（十）一株總粒數：處理間及品種間均呈極顯著差異（表 5）。T_3 處理對三品種均有顯著增加之效果， T_4 處理則對臺農 67 號有增進效果，但對早熟稻品種日本晴及廣陸矮 4 號則稍有減少之趨勢（表 4）。

（十一）結實率：處理間及品種間之差異均顯著（表 5），施用生長素之 T_2、T_3 及 T_4 處理，較之未施用之 T_1 處理，對結實率均有促進效果，尤以廣陸矮 4 號之 T_3 處理有顯著之效果（表4）。

（十二）千粒重：只有處理間之差異極顯著，其他變因則不顯著（表 5）。 T_3 處理對千粒重有增加之效應， T_4 處理却使千粒重下降（表 4）。

（十三）產量：各處理組合之穀粒產量經變方分析結果，無論處理間或品種間均呈極顯著之差異（表 7），比較不同處理間穀粒平均收量，則以加施 SNA+SNP 之 T_3 處理最高，較其他處理有顯著之增加效果（表 4）。

表 7. 一、二期作不同生長素與品種處理組合穀粒產量之變方分析表

Table 7. ANOVA of grain yield between different treatments (I. II crop)

變因 S. O. V	自由度 D. F.	均方 M. S.		F 值 F Value	
		I	II	I	II
區集 B	3	88504.796	5026.403	1.5663	0.7206
處理 T	3	204849.465	320661.704	3.6253	45.9718**
主區機差 Ea	9	56506.129	6976.177	—	—
品種 V	2	2050816.934	553560.556	32.0198**	29.6126**
處理×品種 T×V	6	31075.992	25729.096	0.4852	1.3764
副區機差 Eb	24	64048.481	18693.402	—	—
總計 Total	47	—	—	—	—

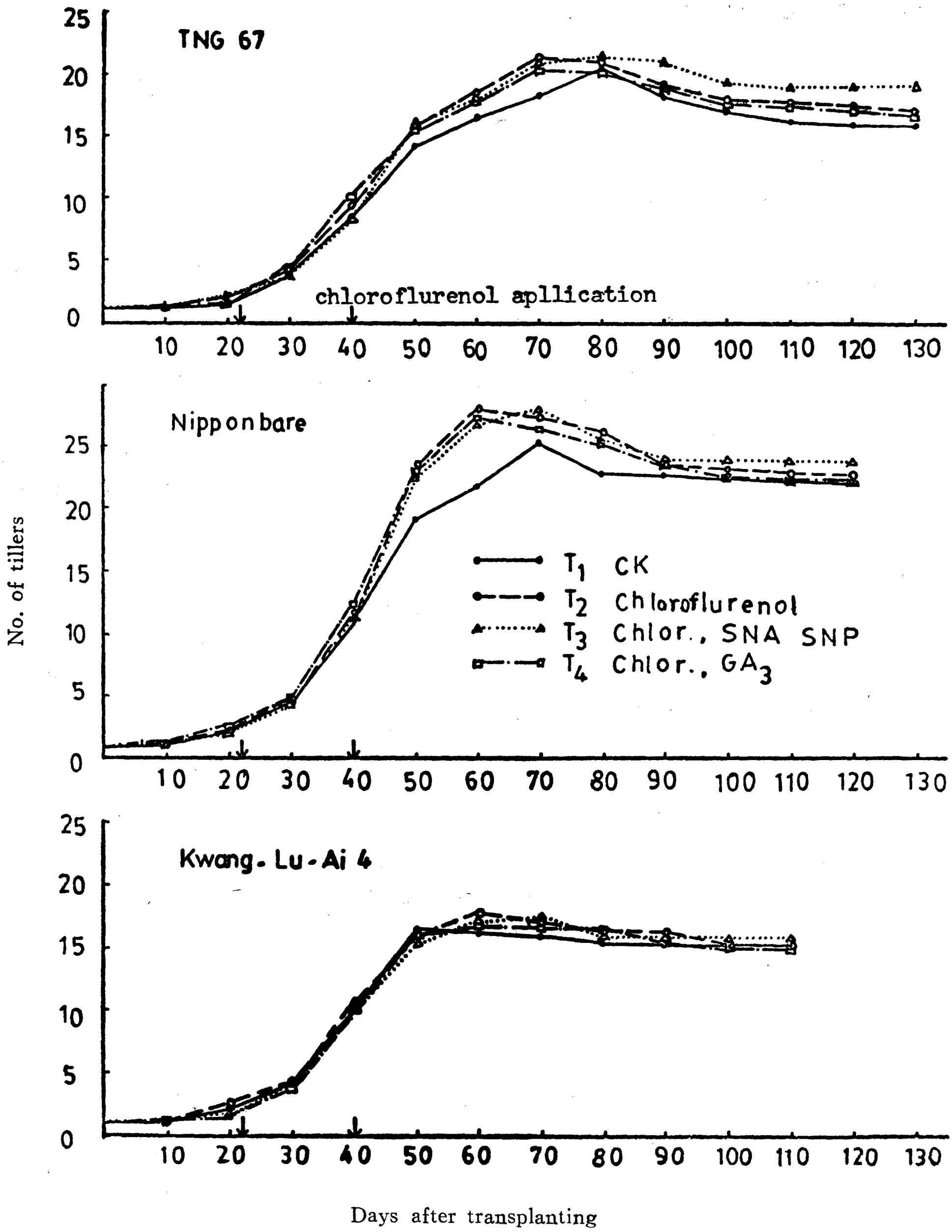

圖 1. 不同生長素處理分蘗數之變化（I期作）

Fig. 1. Changs in tiller number during growth stage with different treatments. (1st crop)

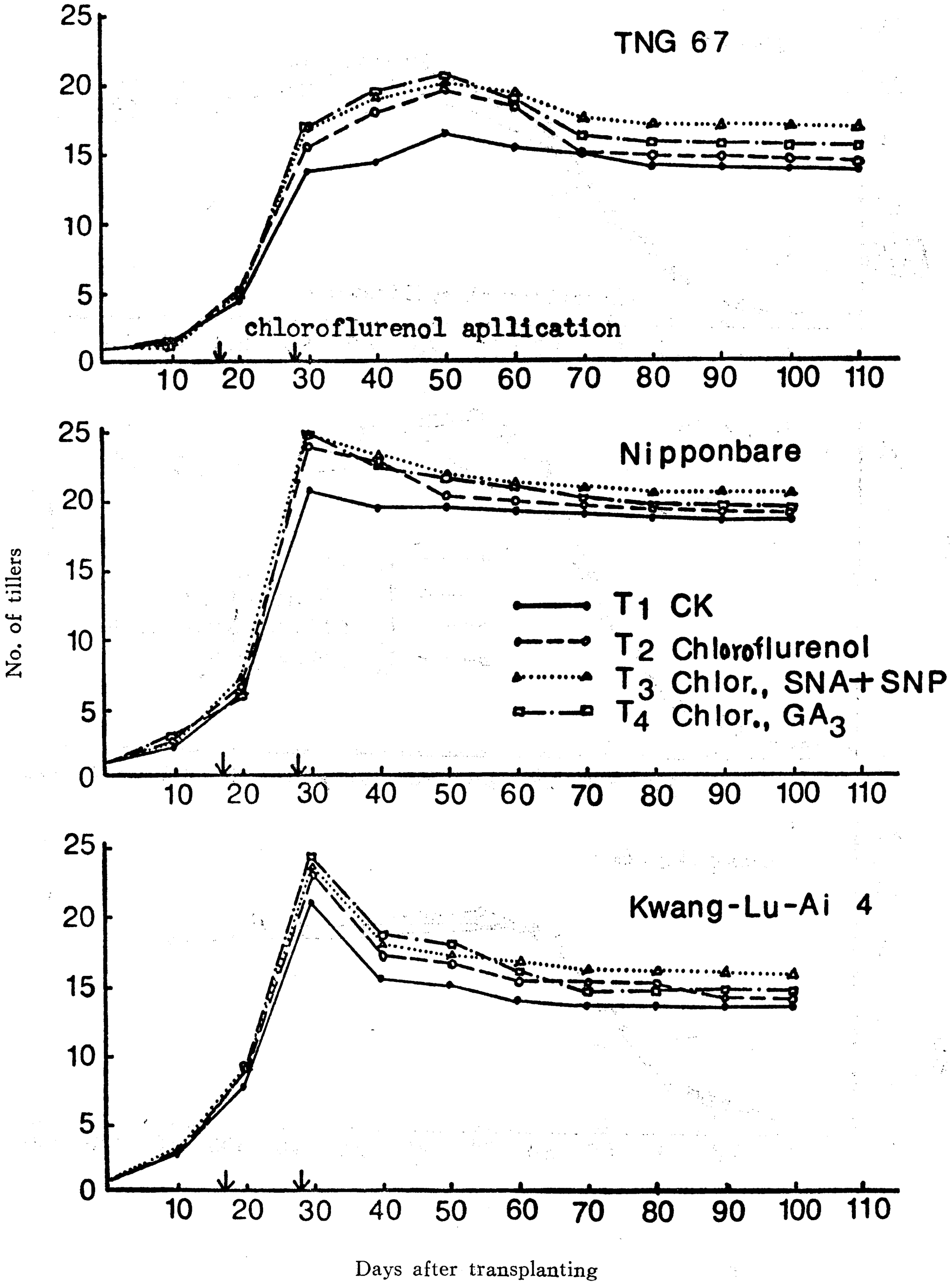

圖 2. 不同生長素處理分蘗數之變化（II期作）

Fig. 2. Changs in tiller number during growth stage with different treatments. (2nd crop)

討　論

一、一、二期作對不同生長素處理及品種之反應

一、二期作對各品種及各生長素處理之反應，一般而言，大體表現均很一致，但在粒長效應方面，臺農 67 號之粒長，在二期作中顯著變短（表 4）。結實率方面，一期作各處理對結實率無顯著差異存在，但在二期作時則有顯著之影響，各品種以施用 SNA+SNP 之 T_3 處理之結實率特高，因此，T_3 處理在二期作之環境下對結實率有較好之增加效果（表 4）。千粒重之影響，一期作中各處理間無差異，品種間呈顯著差異（表 2），在二期作中則各品種間差異不顯著，處理間之差異爲極顯著（表 5），且以 T_3 處理對千粒重有較大之效應，因之，由於在二期作中，施用生長素對結實率及千粒重較一期作有更大之效果，此即爲施用生長素對產量之增加效果二期作要比一期作大之主要原因。

二、施用 Chloroflurenol 對一、二期稻作之效果

於水稻分蘖開始期及分蘖盛期施用 Chloroflurenol，對一、二期作水稻分蘖數有顯著增加之效果（圖 1.2.）。Chloroflurenol 爲一種 auxin 運移抑制劑，其所以能促進分蘖可能機制是抑制頂芽 auxin 之運移[7,10]，而與根部向上運移之 cytokinin 無關[9]。張等[4]並曾以 Chloroflurenol 5 mM 濃度處理水稻，結果其促進分蘖高達約 2 倍。

Chloroflurenol 處理雖使分蘖數顯著增加（一期作增加 3～12 %，二期作增加 9～19 %），然對於一株穗數並未顯著增加，此表示所增加之分蘖大部分爲無效分蘖，或雖有孕穗現象而不能抽穗結實。施用 Chloroflurenol 對一穗粒數或一株總粒數均有減少之趨勢（表 14），一穗粒數減少，可能是由於所形成之無效分蘖使養份消耗，或由於所形成之小分蘖受上部葉片遮光影響，使光合作用降低，而其呼吸作用仍耗用乾物質之結果，導致一穗穎花數減少，千粒重降低[18]。因此，Chloroflurenol 處理對產量之影響並無顯著效果，二期作中臺農 67 號及日本晴施用 Chloroflurenol 處理對產量且有下降之趨勢，因二期作後期之低溝寡日照已限制產量，再由於 T_2 處理增加無效分蘖，消耗光合作用產物，因此，除廣陸矮 4 號由於穗數增加而未減產外，日本晴及臺農 67 號由於千粒重降低，因而使產量降低（表 4）。

三、施用 SNA+SNP 混合液處理對一、二期作水稻之效果

各品種之 T_3 處理對一、二期水稻之農藝性狀及產量構成因素有很好之效應，其使最高分蘖數及一株穗數顯著提高（表 1、4）亦即由於前期施用 Chloroflurenol 使分蘖增加，後期再加施 SNA+SNP 時，可使得增加之大部分無效分蘖抽穗結實，成爲有效分蘖，一株平均穗數因而增加，但這些由無效分蘖轉變爲有效分蘖所產生之穗，一般較短小，因而使一穗平均粒數降低，然而以一株總粒數計，則 T_3 處理，一、二期作均有顯著增加之效果（表 1、4）。

T_3 處理對稻穗穎花之分化與發育亦有顯著之效果，如不計小穗而以正常之稻穗調查之結果，T_3 處理使一穗平均穎花數顯著提高，亦即是由於發育穎花數增加，以及退化穎花數減少之結果。發育穎花數之增加，乃由於二次枝梗上之發育穎花數顯著增加之效果（表3、6），此顯示 SNA 和 SNP 對稻穗分化有良好之促進效果。

施用 SNA+SNP 混合液之 T_3 處理較未施用 SNA+SNP 之 T_2 處理，對於結實率、千粒重有增加之效果，尤以二期作之效果更爲顯著（表 1、4）。此外，T_3 處理亦有增大穗長之顯著效果。施等[3]報告，含 sodiumnitrophenol 之「利多性」 2,000 倍稀釋液能提高水稻稔實率、一株穗數等，本實驗亦有相同之結果。

T_3 處理由於一株穗數、一穗發育穎花數、結實率顯著提高，因而使得產量顯著提高，其增加之效果，一期作增加 4—11 %，二期作增則加 5—14 %（表 1、4），二期作之增加效果所以較一期作高之原因，可能由於施用 SNA+SNP 可以消除環境對二期作減產之部分限制因子。

四、施用 GA_3 處理對一、二期水稻之效果

GA_3 對植物之效應最大特性爲引起莖之節間伸長以及對葉長、葉寬顯著之增加[15]，尤其對矮型水稻品種，此等特性更爲明顯，且常用做爲 GA 反應之生物檢定法[17]。本試驗中 GA_3 處理，亦對矮型之早熟稻品種日本晴及廣陸矮 4 號有顯著之增高效果； GA_3 亦使穗長、粒長增加，及葉色變淡，葉變寬等，其他之影響爲一株粒數之增加，結實率、千粒重之減少等（表 1、4）。

GA_3 處理對一株穗數亦有增加之效應，此乃由於施用 GA_3 後有促進抽穗之效果，即能使一些由於前期施用 Chloroflurenol 而增加之分蘖促進其抽穗，使一株平均穗數增加，但在二期作後期因養分競爭不力而枯死，故穗數之增加並不顯著。又由於 GA_3 之施用，使得株桿細長而易於彎折，變爲不適株型，因此影響其後期發育，致使結實率、千粒重均下降，一期作尚能由於穗數及一株粒數之增加而使得臺農 67 號及日本晴稉型水稻增產 1～2 %（表 1），但在二期作却由於千粒重顯著下降而使產量減少 2～3 % 表（4）。

五、不同品種間其產量及產量構成因素之差異

不同生長素及品種處理組合間主要農藝性狀及產量構成因素經變方分析均方顯著性測驗結果，品種間之差異一期作除粒長及穗長不顯著外，其他性狀均呈顯著或極顯著之差異（表 2）二期作除了千粒重不顯著外，其他性狀均呈顯著或極顯著之差異（表 5），各品種對各處理之反應不同，臺農 67 號對不同生長處理有較好之反應，稉型早熟稻日本晴分蘖性特強，由施用 Chloroflurenol 而促使分蘖數增加之效果亦大，但其千粒重却降低。 秈型早熟品種廣陸矮 4 號對施用 Chloroflurenol，SNA+SNP 及 GA_3 處理，在一株穗數、千粒重及株高之增加效應方面，均較其他供試品種要大。對於產量增加效果方面，臺農 67 號增加最大，廣陸 4 號次之，日本晴則效果較小（表 1）。

參考文獻

1. 卜瑞雄、黃真生、陳正昌。 1978 。稻減數分裂期及成熟期施用蔗糖之增產研究。中華農業研究 27：169-174。
2. 周惠慈。 1970 。數種生長物質對水稻生長及產量效應之研究。國立中興大學理工學報 12：335-350。
3. 施景恒、張和、楊遜謙、吳育郎。 1978 。葉面施肥及施用生長調節素對二期稻產量之影響。科學發展月刊 6(1)：17-35 。
4. 張唯勤、徐美珠、邱寶玲、陳學貞。 1978 。植物生長素與水稻分蘖一控制分蘖之荷爾蒙因子，一、二期稻作根系 cytokinin 活性比較及 auxin 運移抑制劑促進分蘖。科學發展月刊 6(2)：148-153。
5. 鄔宏潘、廖雲英、錢美華、林燦隆、陳一心、王銀波、蔡國海、吳來貴、張萬來、林富雄、吳育郎。 1975。第二期稻作低產原因之探討。科學發展月刊 3(10)：5-39。
6. 臺灣省農業試驗所。 1979 。耐寒早熟水稻品種與輪作關係之試驗研究。民國六十七年度結果報告（油印本）。
7. Beyer, E. M., Jr. 1972. Auxin transport : A new synthetic inhibitor. Plant Physiol. 50 : 322-327.
8. Bhallacharya, A. and S. Tokumasu. 1970. Effect of gibberellin upon sex expression and internode length in gynoecious and monoecious cucumber. J. Japaness Soc. Hort. Sci. 39 : 224-231.
9. Chang, W. C. and J. R. Goodin. 1974. The role of root system in laternal bud growth of pea. Bot. Bull. Acad. Sinica 15 : 122-132.
10. Chang, W. C. 1975. Apical dominance in pea : Effect of morphactin on transport of auxin and kinetin. Bot. Bull. Acad. Sinica 16 : 83-94.
11. Cleland, C. F. and W. S. Briggs. 1969. Gibberellin and CCC effects on flowering and growth in the long-day plant *Lemna gibba* G3. Plant Physiol. 44 : 503-507.
12. Huang, C. S. 1977. Causes of low yields of the second crop rice. Jour. Agric. Assoc. China NS 100 : 22-33.
13. Hu, C. H. 1973. Evalution of breeding semidwarf rice by induced mutation and hybridization.

Euphytica 22 : 562-574.

14. Murata, Y. 1969. Physiological responses to nitrogen in plants. *In* physiological aspects of crop yield (J. D. Eastin *et al* ed.) ASA and CSSA, Madison, Wisc.
15. Rappaport, L. 1957. Effect of gibberellin on growth, flowering and fruiting of the earlypak tomato, *Lycopersicum esculentum*. Plant Physiol. 32 : 440-444.
16. Schneider, G. 1970. Morphactins : Physiology and performance. Ann. Rev. Plant Physiol. 21 : 499-536.
17. Tung, M. S. 1975. Growth response of germination dwarf rice seeds to gibberellic acid. J. Sci. Eng., (Natl. Chung-Hsing Univ.) 11 : 351-354.
18. Vergara, B. S., A. Tanaka., R. Lilis. and S. Puranabhavung. 1966. Relationship between growth duration and grain yield of rice plants. Soil Sci. Plant Nutrient. 12 : 31-39.

Effects of the application of plant growth regulators on yield components of early maturing rice[1]

R. H. Buu and C. S. Huang[2]

Summary

A sudy was carried out to investigate the effects of plant growth regulators, chloroflurenol (IT 3456, methl-2-chloro-9-hydroxy-fluroene-9-carboxylate ; 1 mM), SNA (sodium naphthalene acetic acid ; 50 ppm) +SNP (sodium nitrophenol ; 2000 X) and gibberellin (GA_3 ; 50 ppm) on grain yield and yield components of paddy rice. Two early maturing rice Nipponbare, Kwang-lu-ai 4 and the local cultivar Tainung 67 were used in this experiment. The following results were obtained.

1. The application of chloroflurenol alone increased tiller number per plant by 3-12% in the first rice season and by 9-19% in the second season. However, most of the increased tillers did not bear panicles. No striking effect on grain yield was obtained since mean spikelet number per panicle and 1000-grain-weight were reduced by this treatment.

2. SNA and SNP mixture treatment showed the effects of increasing panicle number, particularly by promoting the additional tillers caused by chloroflurenol treatment to bear effective panicles. Number of florets in the secondary branch position, seed-set percentage and 1000-grain-weight were also increased, especially in the second crop season. Grain yield was increased by 4-11% and 5-14% in the first and second rice seasons, respectly.

3. GA_3 treatment significantly affected the plant height and length of panicles and

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spikelets. Most significant effect was found on the semi-dwarf variety Kwang-lu-ai 4. Spikelet number per plant and seed-set percentage also increased slightly, whereas 1000-grain-weight dropped. Other agronomic characters showed relatively unstable results. This treatment caused the reduction of grain yield of Kwang-lu-ai 4 in the first and of all cultivars in the second crop season.

4. Highly significant differences in grain yield and yield components were found among the three cultivars tested. Different growth regulator treatments had more favourable influence on Tainung 67 than on other cultivars, particularly in grain yield. The application of chloroflurenol could increase the tiller number of Nipponbare, but not 1000-grain-weight and grain yield. The treatment of chloroflurenol, SNA+SNP, and GA_3 had more favorable influence on the panicle number per plant, 1000-grain-weight and plant height for Kwang-lu-ai 4 than for other cultivars, and its grain yield showed a slight increase also.

中華農業硏究 (Jour. Agric. Res. China) 29(2)：131～136 (1980)

由花藥培養誘得單元體水稻倍加品系田間表現之初步觀察[1]

郭益全　林明華　謝順景[2]

摘要：本研究爲了初步檢討水稻花藥培養所育成雙單元體植株之育種價值，乃選用遺傳質純接合稻株之花藥所誘得雙單元體品系進行本試驗。結果發現：從花藥之培養到雙單元體植株之誘導的整個過程中，產量4要素之有關遺傳因子極可能發生各類不易查覺之突變，且突變後之遺傳因子對本省一、二期作生育環境之適應能力也有若干程度之差異。文中曾就此等結果加以討論，並據此等結果推論水稻之花藥培養應有利於雜接合育種集團遺傳多樣性之擴大，而實際俾益於新品種之選育。

水稻之花藥經培養後，除了可獲得單元體之植株外，尙可產生大量的二元體及少數之多元體植株[3,5-7,9-14]。而這些單元體植物得經由秋水仙素 (Colchicine) 之處理，行染色體之人工倍加以獲致雙單元體之水稻植株[1,8]；或將這些單元體植株之器官或組織於添加有某特殊化學成份（例如 2, 4-D）之培養基上行繼代培養 (subcultare)，亦可誘得遺傳質純接合之雙單元體植株[1]。至於那些非單元體植株之來源，據 Chen (1977) 之研究推論，認爲此可能係花粉在早期發育過程中，細胞之核融合 (nuclear fusion) 所造成的[5]。因爲這些二元體理論上都是完全同基因型的 (completely homozygous) 個體，所以水稻之花藥培養在水稻之遺傳及育種上具有高度的實用價值[3]。

臺灣省農業試驗所農藝系遺傳硏究室已成功地連續由水稻之花藥培養誘導出各種倍數體之植株，並已培育成許多性狀表現安定而不分離的固定品系。惟，過去之硏究工作概偏重於最適培養基之究明[4,6,14]，內在適期花粉發育時期之決定[1,2,5]與外在培養環境之影響[1,2,4]，癒合組織 (callus) 再分化率的提高與白苗率之控制[4]，單元體植物之倍加技術[8]及各類單、雙及多元體植物之來源與其形成之機制[1,2,5,9,11,13]等基本問題的探討，而尙未盡力於誘得雙單元體植物在遺傳與育種等實用價值方面之觀察和檢討。

鑑此，筆者等乃由本硏究室現保存之100多個品系中，逢機選用經秋水仙素處理單元體稻株而得之人工倍加的雙單元體品系2個；由單元體植株繼代宿根繁殖過程中而獲之自然倍加的雙單元體品2個及花藥親臺中 65 號等5個材料，行一年兩期作之栽培，以初步檢討由花藥培養所誘得雙單元體品系之表現。

材料與方法

本硏究的水稻材料係逢機選自本硏究室以臺中 65 號之花藥所培育成之雙單元體品系。其來源說明詳表1。

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1. 臺灣省農業試驗所 硏究報告 第 922 號
2. 本所農藝系技士及技正兼系主任。臺灣省 臺中縣 霧峰鄉。

表 1. 試驗材料

Table 1. Experimental materials used

Materials	Source
Taichung 65	Original variety
T-11	Naturally occurred doubled-haploid through anther culture
T-12	Naturally occurred doubled-haploid through anther culture
T-29	Doubled-haploid derived by colchicine treatment through anther culture
T-30	Doubled-haploid derived by colchicine treatment through anther culture

試驗在臺中縣萬豐本所試驗農場進行。田間設計採逢機完全區集設計，二重覆。1 期作 1978 年 1月 19 日播種， 2 月 27 日插秧，肥料用量 N：P：K=120：40：40 (kg/ha) ；2 期作 1978 年 7 月 13 插種， 8 月 3 日插秧，肥料用量 N：P：K=100：20：40 (kg/ha) 。行株距 25×25cm ，每小區插 3 行，每行 12 株，成熟時收獲調查中間 10 株。調查項目計有抽穗期（據此及播種期以換算為生育日數）、株高、穗數、穗長、穗重，平均一穗穎花數、結實率、千粒重及單株穀產量等九個性狀。

結 果

一、供試雙單元體系統各農藝性狀之變力分析

將所調查之 9 個性狀，以期作及材料為處理行二因子之逢機完全區集的複因子變力分析，其分析結果列於表 2 。

表 2. 各性狀之變方分析

Table 2. Analysis of variance for various characters

Source of variation	D. f.	Growth[1] duration (day)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Panicle number	Spikelet number	Seed setting (%)	1,000 grain wt. (g)	Yield /per plant (g)
Block	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
Materials (M)	4	ns	ns	ns	ns	ns	*	ns	*	*
Crops (C)	1	**	**	**	**	ns	**	**	**	**
M×C	4	ns	ns	ns	ns	ns	ns	ns	ns	*

1. from sowing to heading.　　ns. nonsiginificant.

*. siginificant at 5% level.　　**. siginificant at 1% level.

細察表 2 知，各性狀區集間之差異均不顯著，表示本試驗之設計對土壤差異之局部控制尚稱得當，亦即本試驗之設計尚稱精密，試驗之結果應屬正確詳實，結果之推論亦應合理可信。

由同表可知，本研究供試材料間之各性狀大致上概無顯着差異存在，僅平均一穗穎花數、千粒重及單株穀產量之差異達 5％ 之顯著水準，暗示有關控制複合性狀產量之諸數量因子（polygene）在花藥之培養到雙單元體植株之誘導的過程中，可能發生或多或少之不易察覺的突變。而調查性狀在兩期作之表現，則除穗數外餘均有極顯著之差異存在，顯示期作對供試諸雙單元體系統各性狀之表現

有相當程度之影響。至於供試材料與期作之交感作用，則僅僅單株穀產量顯著，意即在兩期作生育環境下，供試材料單株之穀產量的表現出豐產抑低產之情形，材料間並不十分一致。

二、供試雙單元體系統各性狀之比較

變力分析表（表2）所示數據僅將供試材料之調查性狀作一綜合性之分析，因而材料間個別性之實質差異則無法現出端倪，故將調查性狀按期作之不同分別把 5 個供試材料作進一步之平均值比較。其結果列如表 3 及表 4 。

表 3. 雙單元體各性狀之表現（1978 1期作）

Table 3. Performance of various characters of doubled-haploid rice (1978 1st. crop)

Materials	Growth[1] duration (day)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Panicle number	Spikelet number	Seed setting (%)	1,000 grain wt. (g)	Yield/per plant (g)
Taichung 65	101[2] a	104 a b	20.0 a	2.49 a	10 a	90 a c	96 a	28.18 a	24.08 a
T-11	101 a	99 a	20.2 a	2.39 a	8 a	85 a b	95 a	27.68 a	17.23 b
T-12	101 a	101 a	20.7 a	2.32 a	9 a	82 b	95 a	27.96 a	18.68 b
T-29	102 a	110 a	19.8 a	2.57 a	10 a	95 a c	95 a	26.64 b	23.29 a
T-30	102 a	105 a b	20.5 a	2.57 a	10 a	93 a c	95 a	27.25 a b	23.16 a

1. from sowing to heading
2. means followed by the same letter are not significantly different at 5% level

表 4. 雙單元體各性狀之表現（1978 2期作）

Table 4. Performance of various characters of doubled-haploid rice (1978 2nd. crop)

Materials	Growth[1] duration (day)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Panicle number	Spikelet number	Seed setting (%)	1,000 grain wt. (g)	Yield/per plant (g)
Taichung 65	80[2] a	119 a	24.5 a	2.18 a	10 a	123 a	62 a	23.08 a	16.58 a
T-11	80 a	113 a	24.4 a	2.04 a	10 a	119 a	60 a	23.03 a	16.04 a
T-12	81 a	113 a	24.2 a	1.95 a	10 a	107 b	62 a	23.45 a	14.72 b
T-29	81 a	118 a	24.9 a	1.93 a	10 a	124 a	54 b	21.85 b	14.24 b
T-30	80 a	119 a	25.0 a	2.00 a	10 a	117 a	58 a b	22.44 a b	16.51 a

1. from sowing to heading
2. means followed by the same letter are not siginificantly different at 5% level

綜覽兩表知：在1期作之生育環境下，產量有關之性狀中，僅 T-11 及 T-12 兩系統之平均一穗穎花數及單株穀產量較差， T-29 系統千粒重較輕。而其他農藝性狀之表現則 T-11 及 T--12 兩系統之植株略矮，其餘諸性狀之表現材料間幾無差異存在（表 3 ）。而各材料在 2 期作之表現，則 T-12 系統之平均一穗穎花數與單株穀產量及 T-29 系統之結實率、千粒重與單株穀產量之表現略遜（表 4 ）。

三、供試雙單元體系統各性狀之期作間差異

本省稻作之栽培年有兩期。但因為兩期作之生育環境迥然不同，雖相同品種栽培於相同地點，其性狀之表現亦自不同；且性狀表現之期作間的差異程度亦隨品種之不同而不同，而與供試材料之安定

性 (stability) 有關。本研究爲了便於不同性狀間差異程度之比較，曾將供試材料諸性狀之兩期作間差異之絕對值對兩期作值之和求比值，以初步描述供試材料性狀表現之期作間的安定程度，其值則示於表 5。綜觀表 5 而知，由水稻臺中 65 號之花藥，經培養誘得的 4 個雙單元體系統各性狀表現之期作間差異，概與原花藥親本相似，並皆以結實率之期作間差異最大，而以穗數之變異最小。而若就不同材料之同一性狀言，則除單株穀產量之變異較大外，餘各材料同性狀之期作間差異的變異程度則尚稱一致。

表 5. 雙單元體各性狀在兩期作間之差異

Table 5. Difference in various characters of doubled-haploid rice between the first and second crop season

Materials	Growth[1] duration (day)	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	Panicle number	Spikelet number	Seed setting (%)	1,000 grain wt. (g)	Yield/per plant (g)
Taichung 65	0.1160[2]	0.0673	0.0805	0.0664	0	0.1549	0.2152	0.0995	0.1845
T-11	0.1160	0.0660	0.0942	0.0790	0.0714	0.1667	0.2258	0.0917	0.0295
T-12	0.1099	0.0536	0.0780	0.0867	0.0526	0.1323	0.2101	0.0877	0.1183
T-29	0.1148	0.0351	0.1141	0.1422	0	0.1324	0.2752	0.0988	0.2411
T-30	0.1209	0.0625	0.0989	0.1247	0	0.1143	0.2157	0.0968	0.1676

1. from sowing to heading

2. $\text{value} = \dfrac{|\text{1st. crop} - \text{2nd. crop}|}{\text{1st. crop} + \text{2nd. crop}}$

四、供試雙單元體系統之期作與單株穀產量的交感

由變方分析表中知期作與材料之交感僅單株穀產量顯著 (表 2)，而各材料單株穀產量期作間差異之變異程度又頗大 (表 5)。故本研究特進行期作與各個材料單株穀產量個別交感效應值的進一步估算 (表 6)。結果發現供試材料僅 T-11 及 T-29 兩系統之個別期作交感值達 5% 顯著水準，其餘各材料則皆不顯著。而由交感效應值之是正或負可判定：T-11 系統較適合二期作之栽培，而 T-29 系統則僅一期作之環境下栽培較有利，至於其餘材料雖也有較適一期作或二期作生育條件下栽培較妥善之傾向，但因其個別期作與單株穀產量之交感效應值不顯著，啓示此等材料在任何期作之環境下栽培，均尚可達水準之單株穀產量。

表 6. 單株穀產量之材料與期作間的交感

Table 6. Interaction between materials and crop of grain yield per plant

	Taichung 65	T-11	T-12	T-29	T-30
1978 1st crop	0.94	− 2.36*	− 0.83	1.72*	0.52
1978 2nd crop	− 0.94	2.36*	0.83	− 1.72*	− 0.52

*. siginificant at 5% level

討　論

就理論上言，遺傳質純接合水稻個體之花藥經培養後所誘得的雙單元體植株，其不論是由單元體植株經秋水仙素處理所人工倍加者或經繼代宿根繁殖而自然誘致者，皆應是完全同基因型的（ completely homologous ）個體，亦即這些雙單元體各性狀之表現應與原花藥親者一致。其若發生若干變異，則可能的原因互大別歸成兩類：一爲試驗環境局部差異之控制不當所引起，亦即外在試驗設計不當所造成；二係由花藥培養到雙單元體誘導之整個過程中，控制性狀表現之若干遺傳因子發生不易查覺之小突變 (micromutation) 或大突變（ macromutation ）所造成，亦即爲內在遺傳因素所引起。而本研究中供試材料調查性狀經變方分析結果顯示區集效應不顯著（表２），表示本試驗中所發現供試材料性狀表現之發生若干變異，應非導因於試驗設計之不當所引起。援 Chen 水稻花藥培養發現染色體數 $2n=25$ 植株之事實[5]，再證於本研究所獲得之數據，筆者等肯定地認爲控制性狀表現之主效因子 (major gene) 或微效因子 (minor gene or poly gene)，在花藥之培養到雙單元體植株誘導之整個過程中發生各類突變，才是造成供試材料性狀表現不一之主要原因。

生物本身能經由遺傳及生理之機制而具自我控制的能力，使其在複雜變動的生育環境中，能忍受某些不適的生育條件而正常穩定地維持其生存且茁壯並繁衍後代，此即所謂之自身調整 (homeostasis) 或緩衝（ buffering ）或安定性 (stability) 。本研究中發現供試材料單株穀產量之期作間差異的變異相當大，顯示各供試材料單株穀產量之自身調整能力不一，而一般咸認複合性狀產量是由穗數、一穗穎花數、結實率及千粒重等四要素所成。仔細比較兩期作供試材料產量 4 要素的表現（表３及表４），並參照表５所列各產量要素期作間差異之變異情形，筆者等相當肯定地認爲供試材料單株穀產量安定性之不一，乃源自培養過程中產量４要素發生或多或少之各類突變，同時突變後之遺傳因子在一、二期作生育條件互異的環境中之適應能力又自不一，故由４要素累積相乘效果之複合性狀產量的安定性變異遂最大。亦即筆者等以爲整個培養過程中，有關性狀之遺傳因子不僅有發生各類突變之可能，同時突變後之因子的自身調整能力也不盡相同。也因之，數據顯示雙單元體供試材料中有較適合二期作生育條件下栽培之系統；有較適合一期作栽培之品系；也有兩期作皆能獲得水準穀量之系統（表６）。

綜合本研究發現從遺傳質純接合稻植株花藥之培養中可能獲致各類變異，且突變之遺傳因子對變動之生育環境的適應能力又不盡一致之事實。啓示吾人不僅遺傳質純接合花藥之培養有遺傳育種價值；而若從遺傳質異接合之雜交 F_1 稻株花藥之選用，並使用添加適當誘導劑之培養基行培養，則應更能大大提高雜種花藥集團之遺傳多樣性（ diversity ），而有助吾人更迅速簡單地選獲具目標性狀之因定品系。總言之，即筆者等樂觀地相信，花藥培養不僅在遺傳方面能提供具饒趣的研究材料；即在實際造成育種目標集團之多樣性及縮短育種年限方面也具實用價值。

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引 用 文 獻

1. 陳其昌、張穎、1974・花藥培養與單元體育種　科學農業　22(５－６)：95–103。
2. 陳其昌、1976・水稻花藥培養之研究　花粉時期與低溫處理　科學發展　４(２)：2186–2190。
3. 許淑卿、陳其昌、1977・水稻花藥培養之研究　二元體花藥植株的來源　科學發展　５(10)：834–839。
4. 蔡秀錦、林明華、1977・水稻花藥培養以育成植株之研究　中華農業研究　26(２)：100–112。
5. Chen, C. C. 1977. *In Vitro* development of plants from microspores of rice. In Vitro 13 (8) : 484–489.
6. Chen, C. C. and M. H. Lin. 1976. Induction of rice plantlets from anther culture. Bot. Bull. Academia Sinica 17 : 18–24.
7. Iyer, R. D. and S. K. RAina. 1972. The early ontogeny of embryoids and callus from pollen and

subsquent organogenesis in anther cultures of *Datura metal* and rice. Planta 104 : 146-156.
8. Lin, M. H. 1979. Diploidization of haploid rice plants by colchicine treatment. J. Agri. Res. China 28 (1) : 45-49.
9. Mok, T. and S. C. Woo. 1976. Identification of pollen plants regenerated from anther of an intersubspecific rice hybrid. Bot. Bull. Academia Sinica 17 : 169-174.
10. Nishi, T. and S. Mitsuoka. 1969. Occurence of various ploid plants from anther and ovary culture of rice plant. Jan. J. Genet. 44 : 341-346.
11. Woo, S. C. and I. J. Tung. 1972. Induction of rice plants from hybrid anthers of *indica* and *japonica* cross. Bot. Bull. Academia Sinica 13 : 67-69.
12. Woo, S. C. and H. Y. Su. 1975. Doubled haploid rice from *indica* and *japonica* through anther culture. Bot. Bull. Academia Sinica 16 : 19-24.
13. Woo, S. C., H. Y. Su, C. M. Ng and I. J. Tung. 1973. Seed formation on induced haploid plant and cytology of anther culture callus from hybrid rice. Bot. Bull. Academia Sinica 14 : 61-64.
14. Woo, S. C., T. Mok and J. Y. Huang. 1978. Anther culture of *Oryza sativa* L. and *Oryza perennis* Moench hybrids. Bot. Bull. Academia Sinica 19 : 171-178.

A preliminary observation on field performance of doubled-haploid rice through anther culture[1]

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Summary

The present studies were conducted to evaluate the value of doubled-haploid plants in rice breeding. Four of 100 completely homozygous lines developed through anther culture were randomly selected for field trial. The results of statistical analysis showed that the micromutation of quantitative characters had been induced during the process of doubled haploid development following anther culture. The performance of four major yield components controlled by minor genes as well as mutated genes, differed from crop seasons due to different climatic conditions. The advantages of using hybrid anther for tissue culture to increase the genetic variability of doubled-haploid plants so that to increase the chance of selection had been stressed.

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水稻培養花葯褐變與癒傷組織形成之關係[1]

賴 本 智　蔡 新 聲　紀 迺 淳[2]

摘要：臺農 67 號水稻花葯以六種不同消毒方法處理後培養，結果發現消毒液濃度愈高，消毒時間愈長，會促使花葯愈早褐變，因而造成癒傷組織形成能力的降低；秈稉稻雜交 F_1 之花藥，培養後褐變的早晚，各雜交組合間亦呈褐變早者癒傷組織形成能力低，褐變晚者癒傷組織形成能力高的趨勢。培養花葯在第 4～6 週褐變者癒傷組織形成率最高。培養花葯癒傷組織的產生，約在培養後第 21 至 72 天之間，早於 21 天或晚於 72 天，形成癒傷組織機會極少，絕大多數癒傷組織在培養後 36～51 天間形成。花葯早期褐變所導致癒傷組織形成能力之低下。可能係酚類物質氧化所生之 quinone 產生毒害，不利於小胞子發育形成癒傷組織所致。

利用水稻花葯培養獲得的單元體進行染色體數的倍加，可得完全同質的純二元體 (7,14,20)，這種方式的水稻育種不但能縮短育種時間，且能提高選拔效果，實在是育種工作人員早已嚮往的育種新方法。目前一般作物誘導花葯產生癒傷組織的頻率仍太低 (3,4,20)。因此限制了花葯培養被廣泛的應用於實際的育種工作上。

許多報告指出，花葯褐變之速率與植物體形成之間有明顯的負相關。蔡和林等氏發現水稻花葯接種後，若在 2 週內褐變者癒傷組織就難以形成 (14)。Mii 氏研究菸草花葯的培養，發現花葯培養二週內褐變者，其植物體形成率較低，而且雙核期之花葯比單核期到有絲分裂期者更易褐變 (10)。蔡（未發表）發現培養菸草之花葯愈早褐變者，形成植物體百分率愈低，遲至第 4 週才褐變的花葯，其單元體形成率可高達 94.5%。Anagnostakis 氏及 Bajaj 氏等也發現菸草花葯培養時，若能抑制花葯之褐變，則可增加雄性起源 (Androgenesis) 植物體之形成 (5,6)。

蔡和林等氏發現水稻花葯癒傷組織的形成比率與品種（品系）的特性，期作之時間，及培養基組成份等有顯著的關係 (14)。又許和陳等氏也發現不同雜交組合之花葯產生癒傷組織能力不等，頻度介於 17.8% 至 40.0% 之間，其中以臺南 5 號 ×H-124 雜交 F_1 花葯培養所得 40.0% 之癒傷組織形成百分率最高 (2)。雖然水稻之花葯癒傷組織形成百分率經多年來許多學者的努力已大有進步 (1,2,4)，唯比起其他作物如煙草 (17)，曼陀蘿 (13) 等仍嫌太低；爲配合育種使花葯培養達到實用化的階段，提高花葯癒傷組織形成的能力是我們應努力的目標。本研究之目的在探求花葯因培養前的消毒而導致花葯對癒傷組織形成的影響。

材料與方法

花葯培養所用的材料爲臺農 67 號，F_1-3 (TCS 3/TNG 67//IR30)、F_1-4 (BG 35-2/PI 162319 // Milyang 23), F_1-11 (KSY 104/TNG 67)、F_1-14 (M 9/IR 30)、F_1-15 (M 9/嘉農育 247) 及 F_1-21 (M 9//Tan 1/Ta-Poo-Cho-Z) 等雜交組合之花葯。

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1. 臺灣省農業試驗所 研究報告 第 923 號
2. 本所農藝系技佐、技正及研究助理。臺灣省 臺中縣 霧峰鄉。

雜交 F_1 及臺農 67 號品種之稻穗係採自本所農藝系稻作研究室種植於臺中縣霧峰鄉試驗農場的植株，將劍葉葉耳距下位葉葉耳約 5 cm 時之稻穗連同劍葉摘下，臺農 67 號稻穗以下述六種方法消毒：

T_0：以 70% 的酒精擦拭葉鞘外部後，將幼穗取出。

T_1：將 T_0 方法消毒後之幼穗浸漬於 70% 酒精中消毒 10 秒。

T_2：將 T_0 方法消毒後之幼穗，浸漬於 70% 酒精中 30 秒。

T_3：將 T_2 方法消毒後之幼穗，以 0.5% 的次氯酸鈉消毒 3 分鐘。

T_4：以 1 %次氯酸鈉取代 T_3 之 0.5% 次氯酸鈉。

T_5：以 2 %次氯酸鈉取代 T_3 之 0.5% 次氯酸鈉。

雜交 F_1 之稻穗以 T_3 法消毒。經消毒後之稻穗以無菌水冲洗 3 ～ 4 次，移至含 5 ml 改良液體 MS (Murashige & Skoog) 培養基 (1962) 之 9cm 培養皿上，以鑷子挑取單核期之花葯 (7)，接種於含有 10ml 之改良 MS 固體培養基上，培養基之無機鹽類，除 Na-Fe-EDTA 外均以原配方減半，蔗糖濃度爲 6 %，並加添 α-Naphthalene acetic acid (NAA) 4 mg/l 及 6-Furfurylaminopurine (Kinetin) 2mg/l (2)，培養環境爲光照 16 小時，光强 1000 lux，溫度 27±1°C 以誘導癒傷組織之形成。接種後每隔三天或七天調查花葯褐變及癒傷組織形成情形，花葯呈咖啡色或黑色者均視爲褐變，接種後 90 天停止調查，以二項分佈求出信賴介值，做爲不同處理或不同雜交組合間之比較。

結　　果

花葯培養三天後即開始褐變（圖 1），其褐變百分比六種不同消毒處理間呈現與消毒濃度及時間有正的關係，即消毒濃度越高消毒時間愈長，則褐變愈快，從培養開始至培養一個月左右，都依這種情形褐變，培養一個月後之花葯褐變，六處理間相差漸近約在 75～89% 間，培養二個月後，每處理均有 90% 以上的花葯褐變，超過二個月仍未褐變之花葯，部份仍呈白色，繼續觀察顯示，這種白色花葯不具誘導形成癒傷組織的能力，大概是接種初期即已死亡之故。

消毒較輕之處理如 T_0、T_1、T_2 之花葯，經培養 12～30 天褐變之花葯佔極大比例分別由 12、18、22%，褐變到 76、88、80%，平均約 60% 左右的花葯在此時期褐變，而 T_3、T_4、T_5 同時期所褐變之花葯分别由 38、48、46% 增至 88、87、90%，平均約有 45% 的花葯在此時期褐變，顯示濃度高之消毒方法所培養的花葯較早褐變，而消毒較輕的花葯，培養後之褐變大部份在第 3 ～ 4 週左右。

各種消毒方法間花葯癒傷組織形成的百分比如圖 2 所示；隨著消毒濃度之提高，消毒時間加長，癒傷組織形成率顯著下降，六處理中的 T_1 癒傷組織形成率最高，達 18%，隨消毒液濃度提高，漸次下降，至 T_5 癒傷組織形成百分比，降至最低，約 3 %而已。T_0 處理癒傷組織形成百分率雖低於 T_1 者，但以二項分佈的信賴介值比較之後並無顯著差異。圖 1 、 2 顯示由於消毒的强弱所造成花葯的褐變與癒傷組織形成百分率間有極大的關係。

六種雜交組合 F_1 的花葯培養，圖 3 顯示花葯褐變之速率亦因不同之雜交組合而異，F_1-4 褐變速率最快，其它五種雜交組合之花葯褐變速率相差不大。再由圖 4 得知 F_1-4 之雜交組合癒傷組織形成率僅 1 %而已。而其他五種組合則都在 24～43% 之間，由圖 3 、 4 可明顯看出，花葯褐變之速率與癒傷組織形成百分比間有極明顯的關係存在，即褐變速率愈快的花葯其癒傷組織形成也愈差。

圖 5 顯示臺農 67 號水稻花葯培養，以週爲單位調查花葯褐變的情形及癒傷組織形成能力間之關係，發現花葯褐變的早晚確與癒傷組織之形成率間有負相關關係。圖 5 顯示培養第 1 週即已褐變的花葯，癒傷組織形成率只有約 4 %，隨著褐變的延緩，癒傷組織形成率提高，第 4 週才褐變的花葯癒傷組織形成率可高達 29%，超過第 5 週仍未褐變之花葯其癒傷組織形成率則又降至 20% 左右，此乃

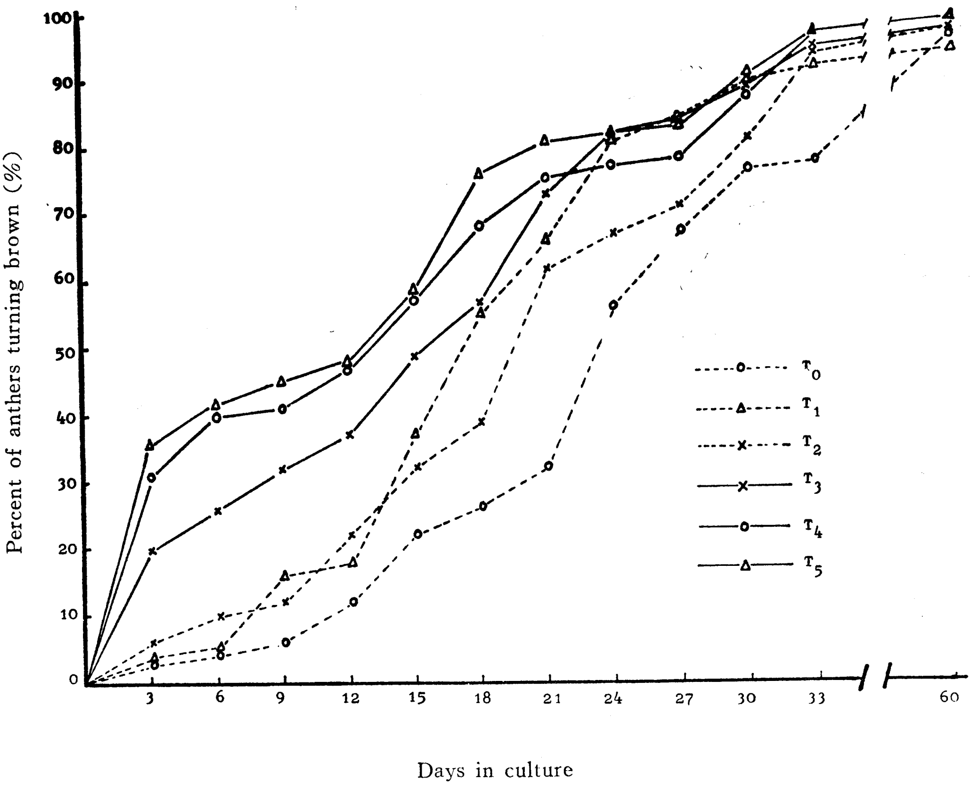

圖1. 臺農 67 號水稻花葯經 6 種不同消毒方法處理，培養後花葯褐變之頻度。T_0： 以 70% 的酒精擦拭葉鞘外部後，將幼穗取出。T_1：將 T_0 方法消毒後之幼穗浸漬於 70% 酒精中 10 秒。T_2：將 T_0 方法消毒後之幼穗浸漬於 70% 酒精中 30 秒，T_3：將 T_2 方法消毒後之幼穗，以 0.5% 的次氯酸鈉消毒 3 分鐘。T_4 以 1 %次氯酸鈉取代 T_3 處理之 0.5% 次氯酸鈉，T_5：以 2 % 次氯酸鈉取代 T_3 處理之 0.5% 次氯酸鈉。

Fig. 1. Frequencies of anthers turning brown from different sterilization method of rice anthers culture. T_0 : flag leaves were surface-sterilized by 70% ethanol. T_1 : inflorescences were sterilized in 70% ethanol for 10 seconds after T_0 treatment. T_2 : inflorescences were sterilized in 70% ethanol for 30 seconds after T_0 treatment. T_3 : inflorescences were sterilized in 0.5% NaClO for 3 minutes after T_2 treatment. T_4 : same as T_3 except 1% NaClO was used. T_5 : same as T_3 except 2% NaClO was used.

因超過第 5 週仍未褐變之花葯含有少許白色的死亡花葯，因而降低其癒傷組織形成率。

圖六顯示臺農 67 號花葯經培養後不同時間褐變之花葯與癒傷組織形成率間之關係。由圖六可明顯看出，經 90 天培養之花葯，每週褐變花葯數佔總培養花葯數之百分比，由第 1 週至第 9 週分別爲 6.42、32.85、30.0、21.19、2.14、1.66、1.42、0.71 及 3.57%，而每週內形成癒傷組織之花葯佔總培養花葯之百分比，由第 1 週至第 9 週，則分別爲 0.23、1.90、1.66、8.57、0.95、0.95、0.47、0.23 及 0.23%，由以上二項資料可得每週內形成癒傷組織之花葯佔該週褐變花葯數之百分比，由第 1 週至第 9 週分別爲 3.7、5.8、5.6、40.4、44.4、57.1、33.3 、 33.3，及 15.2%。即大部份形

成癒傷組織之花葯都在第 4 、5 、6 週間褐變 ，如第 4 週褐變之花葯有 40.4% 可形成癒傷組織，第 5 週褐變者有 44.4%，而第 6 週褐變者更高達 57.1%，若能使培養之花葯遲至培養後第 4 ～ 6 週才褐變，則可大大提高癒傷組織之形成力，培養後第三週以前褐變之花葯，形成癒傷組織機會極少，分別爲 3.7、5.8 及 5.6%，晚於第 7 週才褐變之花葯，形成癒傷組織之能力亦降低，培養第 9 週後仍未褐變者，因含有培養初期即已死亡之花葯，故癒傷組織形成率急速降低。

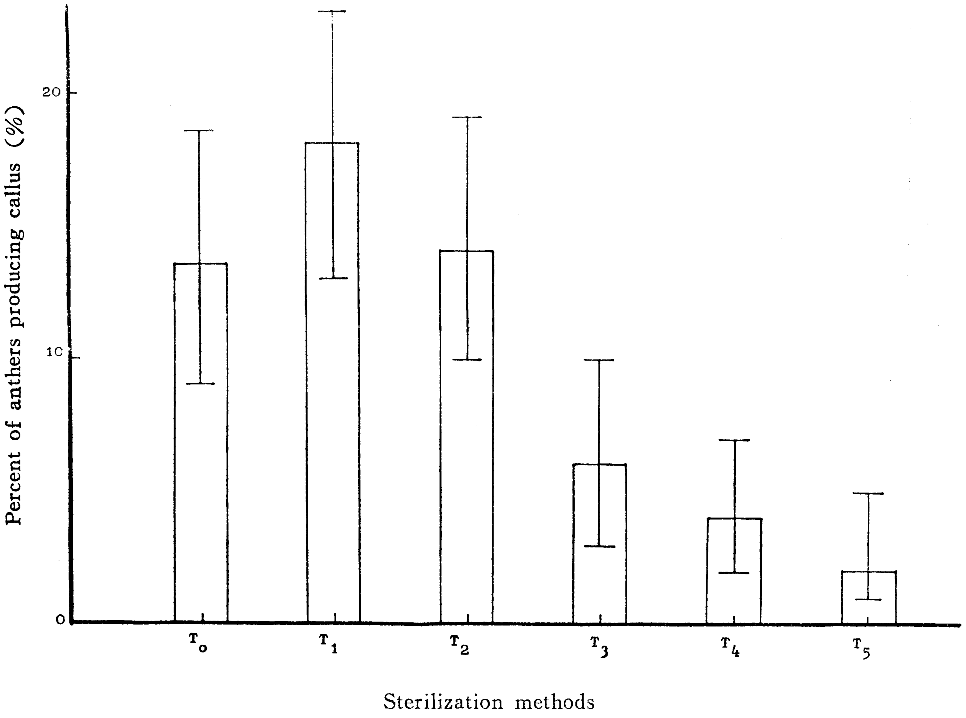

圖2. 臺農 67 號水稻花葯經 6 種不同消毒方法處理，培養後 Callus 形成之頻度 。T_0、T_1、T_2、T_3、T_4、T_5 等六種消毒方法同圖 1 所示。

Fig. 2. Frequencies of callus formation from different sterilization methods of rice anthers culture. T_0 : flag leaves were surface-sterilized by 70% enthanol. T_1 : inflorescences were sterilized in 70% ethanol for 10 seconds after T_0 treatment. T_2 : inflorescences were sterilized in 70% ethanol for 30 seconds after T_0 treatment. T_3 : inflorescences were sterilized in 0.5% NaClO for 3 minutes after T_2 treatment. T_4 : same as T_3 except 1% NaClO was used. T_5 : same as T_3 except 2% NaClO was used.

花葯培養日數與癒傷組織形成的關係，由圖 7 顯示水稻花葯培養約 18 天後才開始形成癒傷組織到 36~51 天時形成癒傷組織頻度最高，以後隨著培養日數之增加而漸減，培養 72 天後則完全停止，消毒液濃度提高似乎可延緩癒傷組織形成之時間，及縮短形成癒傷組織的期限。唯此項結果似乎不大顯著，有更進一步研究之必要。

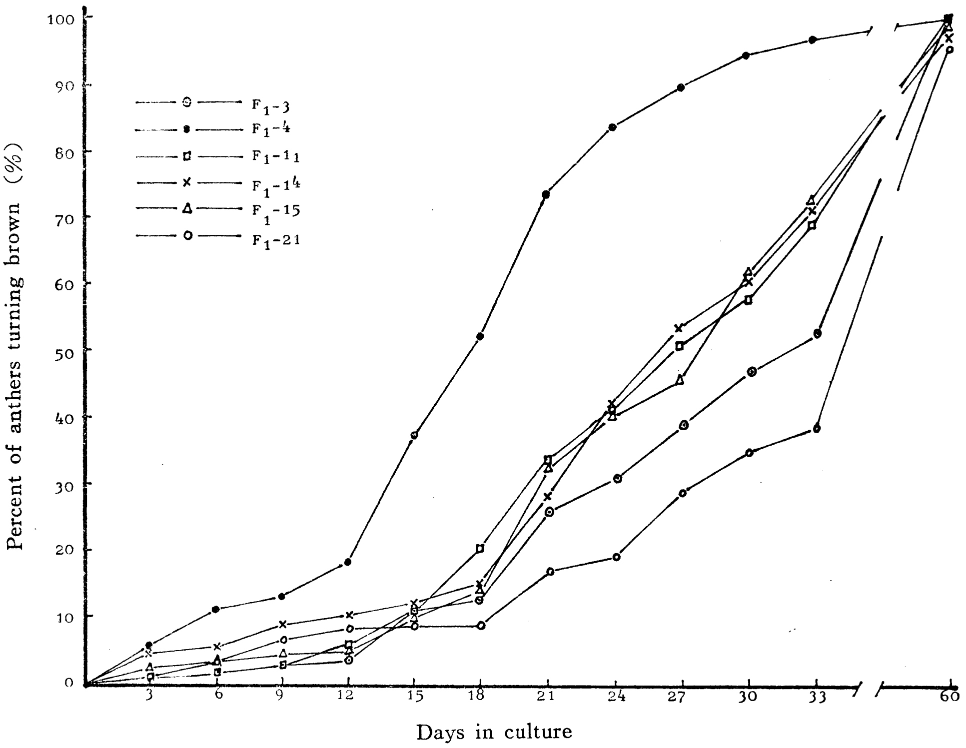

圖 3. 不同雜交組合 F_1 之水稻花葯經 T_3 之消毒方法處理，培養後花葯褐變之頻度。

Fig. 3. Frequencies of anthers turning brown from different F_1 hybrid anthers culture of rice.

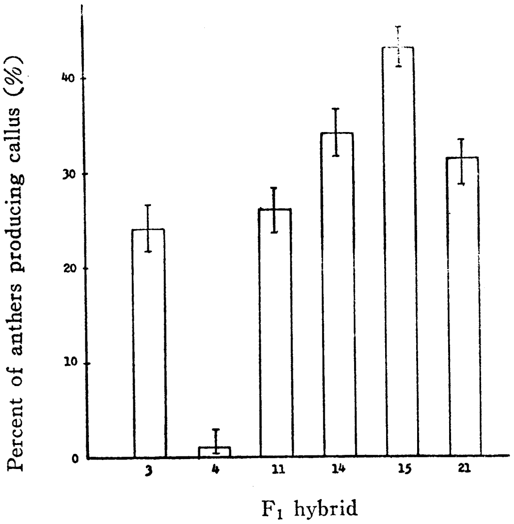

圖 4. 不同雜交組合 F_1 之水稻花葯，培養後 Callus 形成之百分率。

Fig. 4. Varietal difference in the formation of callus of F_1 hybrid anthers culture of rice.

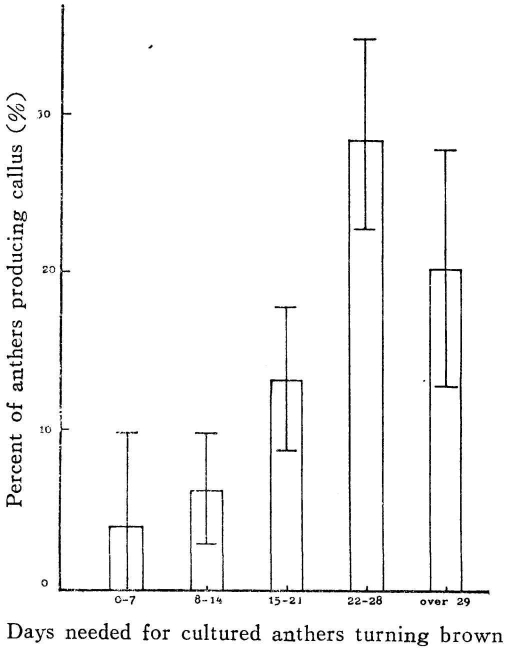

圖 5. 臺農 67 號水稻花葯，培養後花葯褐變與 Callus 形成百分率之關係。

Fig. 5. Relationship of percentage of anthers forming callus and anthers turning brown in rice anthers cultured.

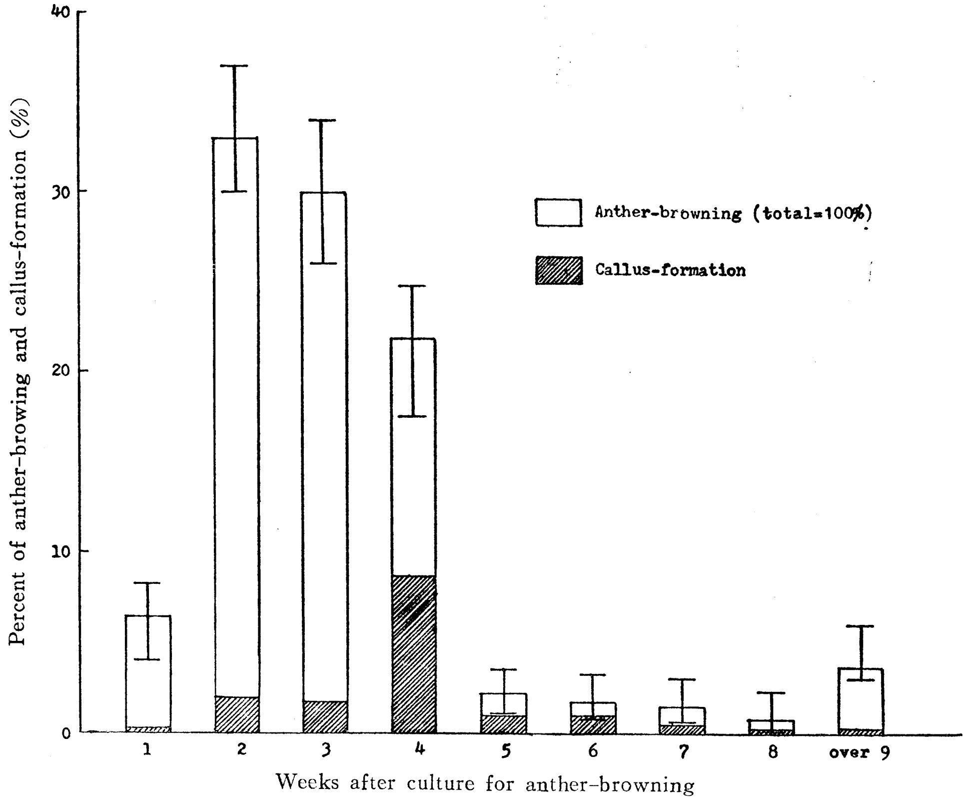

圖 6. 臺農 67 號水稻花葯培養後，不同時間褐變之花葯與 Callus 形成百分率之關係。

Fig. 6. Relation between anther-browning and callus formation of Tainung No. 67 anthers at intervals of culture period.

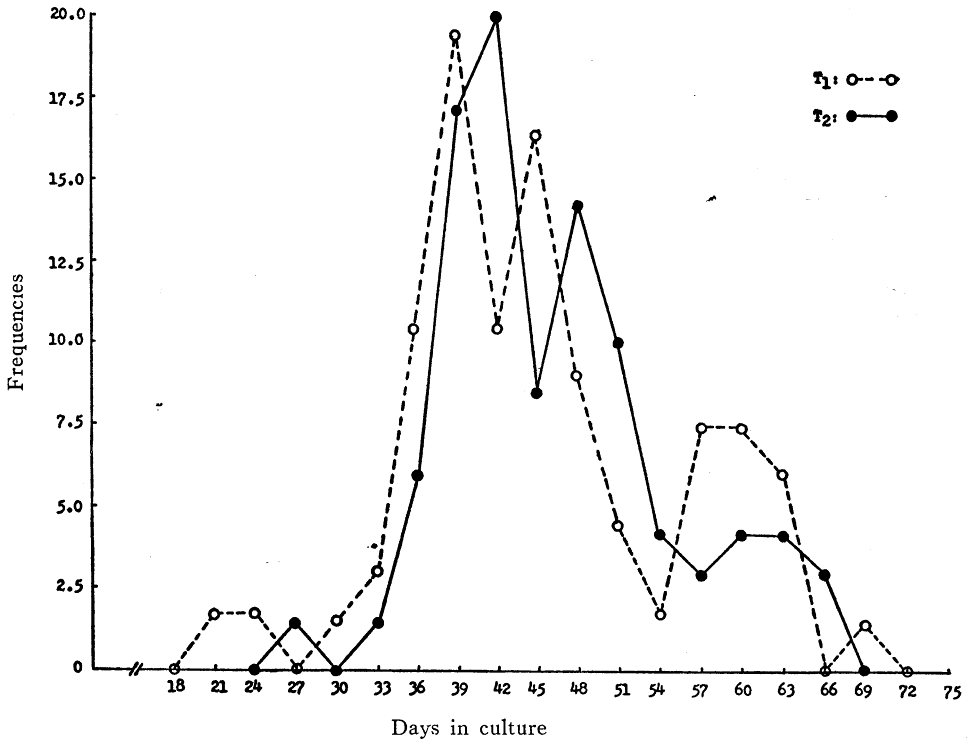

圖 7. 臺農 67 號水稻花葯經 T_1 及 T_2 兩種消毒方法處理，培養後花葯形成 Callus 之頻度，T_1 及 T_2 消毒方法同圖 1 所示。

Fig. 7. Frequencies of anthers producing callus within 75-day culture as affected by different were sterilization methods of Tainung No. 67 rice. Total of 900 samples were observed. T_1 : Flag leaves surface-sterilized by 70% enthanol and inflorescences were sterilized in 70% enthanol for 10 seconds. T_2 : Same as T_1 except 70% enthanol for 30 seconds.

討　　論

花葯壁在花葯培養中所扮演的角色，及因花葯褐變早晚所造成植物體之形成與否，許多文獻均曾提及 [19]，Pelletier 和 Ilami 兩氏 [17] 發現菸草花葯培養超過 25 天才褐變之花葯，產生植物體的能力比早期即已褐變之花葯要好，並且提出花葯褐變現象分爲：（1）急速式褐變。（2）漸近式褐變二型。急速式褐變可能是培養時，從母體植物上切離時受到傷害或生理性的改變所致。而漸近式的褐變，可認爲是花葯本身自然老化的過程；Mii 氏 [10] 報導菸草花葯培養在最初 2 星期即已褐變之花葯，其植物體形成百分比極低，能維持較長時間才褐變之花葯，形成植物體之能力較高，雙核期之花葯比單核期或有絲分裂期更易褐變，他解釋爲雙核期之花葯，因對切離之方式，消毒方法及培養基組成份極爲敏感所致，所以他認爲花葯壁的組織對花粉粒之分裂，可能扮演著一種保護作用。Dunwell 氏 [9] 發表菸草母株於 8 小時短日强光，20°C 下所產生之花葯，因花葯壁中之荷爾蒙正處於誘導花葯形成胚狀體之最佳平衡狀態，故培養後具有較高之植物體形成率。蔡氏（未發表）從事菸草花葯培養，發現第 1 週即已褐變之花葯，不具有形成植物體之能力，第 2 週褐變之花葯有 39% 可形成植物體，第 3 週褐變者則增至 64%，第 4 週以後才褐變之花葯，植物體形成率可高達 94%，本試驗所獲得水稻花葯由於消毒液之强弱及消毒時間之長短所造成花葯褐變之快慢，因而影響到 Callus 形成率的結果與上述諸學者所發表的結果極爲一致。

許多報告均曾强調花葯在花葯培養癒傷組織的形成過程中，扮演者傳送某種未知物質的角色，例如 Sharp, Paskin 及 Sommer 等氏[18] 利用培養於培養基上花葯的表面，隔以一層濾紙的保護培養法 (nurse culture) 培養蕃茄的小胞子獲得成功。利用相同的方法，Pelletier 氏[16]以 *Petunia hybrida* 之花瓣癒傷組織做於草小胞子的保護培養獲得成功。Nitsch 氏[12] 報導培養基中加入曼陀蘿經培養一週後之花葯抽出液，可成功的獲得曼陀蘿小胞子培養的植物體。

爲何花葯褐變過早會影響到癒傷組織形成能力？Loomis 及 Battailer 兩氏[11] 認爲切離組織所含之酚類物質會馬上氧化，使苯環上之氫氧基，被氧化形成 quinone 之有毒物質，造成組織之褐變及傷害，因而抑制了癒傷組織形成。Pelletier 及 Ilammi (1972) 曾提及於草花葯培養時維持培養花葯保持原狀，以使花葯內發育中之胚狀體達到能自行從培養基中吸取養分爲止的一段時間，對單倍體的形成非常重要，Mii 認爲若培養的花葯過早褐變，則褐變所生之有毒物質，將嚴重的影響到胚狀體的發育，而且小胞子也將喪失由花葯壁所供給有利於胚形成或發育之未知物質，因而降低了單倍體植物形成的能力。本研究得知過早褐變之花葯，花粉粒將無法獲得來自花葯壁促進生長分裂之未知物質，因而使癒傷組織或植物體形成率降低，而遲至第 4 週以後才褐變之花葯，却又顯示褐變之物質對癒傷組織形成能力影響較小，其原因可能爲水稻花葯癒傷組織的產生，約在培養 21 天左右開始，陳氏[7]發現培養 20 天之花葯，其花葯壁內花粉粒之發育，已發現分裂爲含有 100 個細胞左右之多細胞現象[7]，這種癒傷組織前身之多細胞體已可利用培養基之養分，不必再依賴細胞壁傳送養分，是故培養第 4 週以後花葯之褐變對發育中的多細胞作用較小。

上述結果顯示水稻花葯壁組織可能在花葯培養過程中提供著保護小胞子的角色，也可能扮演傳送某種與癒傷組織形成有關的重要未知物質，故欲提高水稻花葯癒傷組織形成的能力，首要之務乃如何防止培養花葯早期的褐變，可行的方法如花葯初期的液體振盪培養，活性碳及抗氧化劑 (Antioxidant) 等之利用，或將有益於花葯癒傷組織形成率提高。

引 用 文 獻

1. 林正義、曾美倉、蔡新聲・1974・影響水稻花葯起源 Callus 形成諸因子之研究。國立臺灣大學農學院研究報告 15(2)：1-16。
2. 許淑卿、陳其昌・1977・水稻花葯培養之研究：二元體花葯植株的來源。科學發展月刊 5 (10)：834-839。
3. 陳其昌・1976・水稻花葯培養之研究：花粉時期與低溫處理。科學發展月刊 4 (2)：2187-2190。
4. 蔡秀錦、林明華・1977・水稻花葯培養以育成植株之研究。中華農業研究 26(2)：100-112。
5. Anagnostakis, S. L. 1974. Haploid plants from anthers of tobacco-enhancement with charcoal. Planta 115 : 281-283.
6. Bajaj, Y. P. S. and P. Nitsch, 1975. In vitro propagation of red cabbage (*Brassica oleracea* L. var. capitata). J. Exp. Botany 26 : 883-890.
7. Chen, C. C. 1977. In vitro development of plants from microspores of rice. In Vitro 13 (8) : 484-489.
8. Chen, C. C. 1978. Effects of sucrose concentration on plant production in anther culture of rice. Crop Science 18 : 905-906.
9. Dunwell, J. M. 1976. A comparative study of environmental and developmental factors which influence embryo induction and growth in culture anthers of *Nicotiana tabacum* Environ. Exp. Bot. 16 : 109-119.
10. Mii, M. 1976. Relationships between anther browning and plantlet formation in anther culture of *Nicotiana tabacum* L. Z. Pflanzenphysiol. Bd. 80. S. 206-214.
11. Loomis, W. D., and J. Battaile. 1966. Plant phenolic compounds and the isolation of plant enzymes. Phytochemistry 5 : 423-438.
12. Nitsch, J. P. 1972. Haploid plants from pollen. Z. Pflanzenzüchtg 67 : 3-18.

13. Nitsch, C. and B. Norreel. 1973. Effet dun choc thermique sur le pocevoir embryogene du pollen de *Datura innoxia* cultive dans lanthere ou isole de lanthere. C. R. Acad. Sc. Paris 276 : 303-306.
14. Niizeki, H. and K. Oono. 1971. Rice plants obtained by anther culture. In : Les cultures de plantes. Collogues Internationaux du C. N. R. S. No. 193. Paris : 251-257.
15. Nishi, T. and S. Mitsuoka. 1969. Occurrence of various ploidy plants from anther and ovary culture of rice plant. Jap. J. Genet. 44 : 341-346.
16. Pelletier, G. 1973. Les conditions et les premiers stades de lândrogenése in vitro chez *Nicotiana tabacum*. Soc. Bot. Fr., Memoires : 261-268.
17. Pelletier, G. and M. Ilami. 1972. Les facteurs de landrogenese in vitro chez *Nicotiana tabacum* L. Z. Pflanzenphysiol. Bd. 68. S. 97-114.
18. Sharp, W. R., R. S. Raskin and H. E. Sommer. 1972. The use of nurse culture in the development of haploid clones in tomato. Planta 104 : 357-361.
19. Sunderland, N. 1974. Anther culture as a means of haploid induction. In : Haploids in Higher Plants : Advances and Potential. Kasha, K. J. (Ed.) : 91-122. Univ. Guelph, Guelph.
20. Woo, S. C. and I. J. Tung. 1972. Induction of rice plants from hybrid anthers of Indica and Japonica cross. Bot. Bull. Academia Sinica 13 : 67-69.

The relationship between anther browning and callus formation in rice anther culture

Pen-Chih Lai, Hsin-Sheng Tsay and Nai-Chwen Chi

Summary

Anthers of *Oryza sativa* cv. Tainung No. 67 containing microspores at uninucleate stage were sterilized with six different methods and were cultured at 27°C for 90 days to investigate the relationship between the formation of callus and browning of anthers. It was found that anther browning caused by sterilization reagents severely affected the ability of callus formation. In general, higher concentration or longer duration of sterilization accelerated the browning of cultured anthers and reduced the ability of callus induction.

The culture of F_1 hybrid anthers from six cross combinations of japonica x indica rices also showed the association between earlier anther browning and lower callus formation ability. The anthers turned brown in the later period, e. g., four to six weeks after culture, were shown to possess a greater potential for callus formation than those browned earlier.

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The callus formation started at 21 days and ended at 72 days after culture. the highest pecentage of callus induction from anthers was observed from 36 to 51 days after culture. The low callus formation ability caused by anther browning at early stage was probably due to the production of quinones which are toxic to the microspores.

中華農業研究 (Jour. Agric. Res. China) 29(2): 147~155 (1980)

不同季節生長下母株菸草花葯培養植物體之形成[1]

蔡 新 聲[2]

摘要：利用 Hoagland 液體培養配合不同氮素濃度栽培菸草，以爲花葯培養植物體形成的材料，發現盛夏季節所栽培之菸草，其花葯培養植物體形成能力極差，若再配合過量或不足的氮素量則情形更嚴重；將夏日生長下的菸草花葯以石蠟切片法觀察其內部發育，發現此時期所形成的花葯，有許多是發育不正常的，其花粉囊均爲不正常細胞所佔滿，以至無法形成正常的小胞子，部份花葯雖有小胞子形成，但小胞子數少或許多均屬無功能者，這種情形可能是夏季生長的菸草花葯，培養後植物體形成低下的主要原因。此外，夏日配合過量氮素肥有刺激產生一花多葯的情形，反之缺氮則有形成一花少葯的趨勢。

花葯培養單倍體形成的技術，自 1964 年 Guha 及 Maheshwari[3,4,5] 氏首度在曼陀羅成功以來，其在作物育種改良上的潛力已無庸置疑，最近十多年來已廣受世界各國育種及遺傳學者所重視；爲了獲取足够的單倍體以爲育種材料之用，週年種植母體植物，以爲培養單倍體的材料實屬必要，許多學者在進行週年的花葯培養時，發現許多植物的花葯培養，其植物體的形成具有許多不同的變化；例如Engvild, Linde-Laursen 及 Lundqvist 等氏[2] 即報導曼陀羅花葯培養植物體的形成，在各個試驗中均有些許差異，這種差異是因植物在不同的生長情形下所形成；蔡和林二氏[13] 在從事一、二期作水稻的花葯培養時，得知一期作的結果比二期作好； Madrigal 及Murashige 二氏在從事菸草之週年花葯培養時，亦發現 3 ～ 4 月份所採取的菸草花葯，其植物體形成率最高，夏季 8 ～ 9 月份則最低（私人連繫）；筆者在從事菸草花葯培養植物體形成之研究時，亦發現盛夏季節所採取的花葯，其植物體形成率極差，爲了探求此低下之原因，本研究將生長於 5 ～11月份配合不同氮素量情形下之菸草花葯培養，利用石蠟切片法觀察花葯的發育，以找出盛夏季節裡，花葯培養植物體形成低下的原因。

材料與方法

一、菸草母體植物之栽培

將菸草 Wisconsin 38 號品種之種子播種於 1 ： 1 的 sponge rock 和 Canadian sphagnum 上，再覆以薄薄的一層細砂；當小苗達到葉片展開約 5 cm 寬時，假植到含有加州大學混合 2 號土（UC mix No. 2)的 2 吋塑膠盆上，待株高約10 cm，含有第11片葉時，小心洗淨根部泥土後移植於含有改良 Hoagland (1938)[9] 水耕液的培養基（表 1），爲了避免蒸發過度，3 加侖裝之塑膠栽培盆上覆蓋以三合蔗板，並用以固定菸草植物體，培養液中24小時通氣，全部植物體都生長在噴有白漆以避免溫度過高的溫室內，溫室內之光强在正午時約 30,000 lux。三種不同氮素量之 Hoagland 改良

1. 臺灣省農業試驗所 研究報告 第 930 號。本試驗承美國加州大學 Riverside 分校 Dr. Toshio Murashige 提供試驗所需設備及指導，文成後復承謝主任順景及臺大陳其昌教授斧正，謹此致謝。

2. 本所農藝系技正。臺灣省 臺中縣 霧峰鄉。

水耕液如表2，培養液之 pH 每隔7天調整爲 5.0±0.1 ，培養液初配時爲 12 升，當因蒸散作用而使水耕液降至 10 升以下時，加蒸餾水使重新達 12 升，培養液每 3 ～ 4 星期更換一次。

二、培養基之配製及花葯培養

採取花萼及花冠之比約等於 1 ： 1 的菸草花蕾，以 5 % Purex (含 0.5% NaClO) 消毒 10 分鐘後，再以無菌水清洗數次，然後將花葯自花蕾中取出接種於培養基上。基本培養基採用含有蔗糖 3 %，phytagar 0.8%, thiamine・HCl 0.4 mg/l, inositol 100mg/l 之 Murashige 及 Skoog [10] 基本培養基。pH 在消毒前經調整爲5.7±0.1，以 15 lb/in^2 121°C 高溫高壓消毒 15 分鐘。花葯的採取需特別小心，以避免花葯壁等體細胞組織受到傷害；每個花蕾含 5 個花葯，取其中一個立刻以醋洋紅壓潰法檢定其時期 (Tsay, 1980) [14] ，另取一個固定於 FAA 固定液中以爲組織切片之材料，若檢定發現小胞子發育時期正值第一次有絲分裂期，則將剩餘三個花葯培養於含有 25 ml 裝於 25× 150mm試管之 MS 培養基上，並於 27°±1°C 的恆溫，以 1000 lux 光强每日行 16 小時的照光下培養；資料的獲得是在花葯培養 7 星期後，取出於立體顯微鏡下計算求得，預備試驗顯示培養 7 星期時之花葯單倍體數達到最高。

表 1. Hoagland (1938) 基本培養液的組成份

Table 1. Composition of the Hoagland nutrient medium (1938)

Major elements				Minor elements			
Salts	mM	MW	mg/l	Salts	μM	MW	mg/l
$Ca(NO_3)_2 \cdot 4H_2O$	5	236.1	1181	H_3BO_3	46.0	61.8	2.86
KNO_3	5	101.1	506	$MnCl_2 \cdot 4H_2O^a$	9.1	198.0	1.81
$MgSO_4 \cdot 7H_2O$	2	246.4	493	$CuSO_4 \cdot 5H_2O$	0.3	249.0	0.079
KH_2PO_4	1	104.1	104	$ZnSO_4 \cdot 7H_2O$	0.9	287.0	0.222
Iron tartrate^a	0.5% solution			MoO_3 (85%)^a	0.1	144.0	0.018

a. The original Fe, Mn and Mo sources present in Hoagland solution are modified as following table

Elements	Salts	μM	MW	mg/l
Fe	Na_2-EDTA	200	336.2	37.3
	$FeSO_4 \cdot 7H_2O$	100	277.9	27.8
Mn	$MnSO_4 \cdot H_2O$	9.1	169.0	1.54
Mo	$Na_2MoO_4 \cdot 2H_2O$	0.1	242.2	0.025

三、組織切片法

將小胞子不同發育時期的花葯固定於 FAA 固定液中至少 24小時 ，經一系列不同濃度的 TBA 脫水後封埋於 Paraplast 中 (一種石蠟) ，以鋼刀切片機切取 10μ 厚度 ，以 Heidenhain's iron hematoxylin 染色，再以光學顯微鏡觀察。

結果與討論

圖 1 顯示在夏季 8 ～ 9 月份所做的花葯培養，每個花葯的植物體數均較其它月份所得爲低，雖然圖 2 顯示 8 月份之花葯培養，其產生植物體的花葯仍可高達 60 %，但這種時期的花葯，大多數每個

表 2. Hoagland 爲基礎之各種氮素濃度

Table 2. Nitrogen levels and modifications of Hoagland's solution for culture of tobacco plants.

mM Nitrogen in Culture Solution	Salts	mM	mg/l
	KNO_3	4.5	454.5
4.5	$CaCl_2 \cdot 2H_2O$	5.0	735
	KCl	0.5	37.5
15.0	$Ca\ (NO_3)_2 \cdot 4H_2O$	5.0	1180
	KNO_3	5.0	505
	$Ca\ (NC_3)_2 \cdot 4H_2O$	5.0	1180
45.0	KNO_3	5.0	505
	NH_4NO_3	15.0	1200

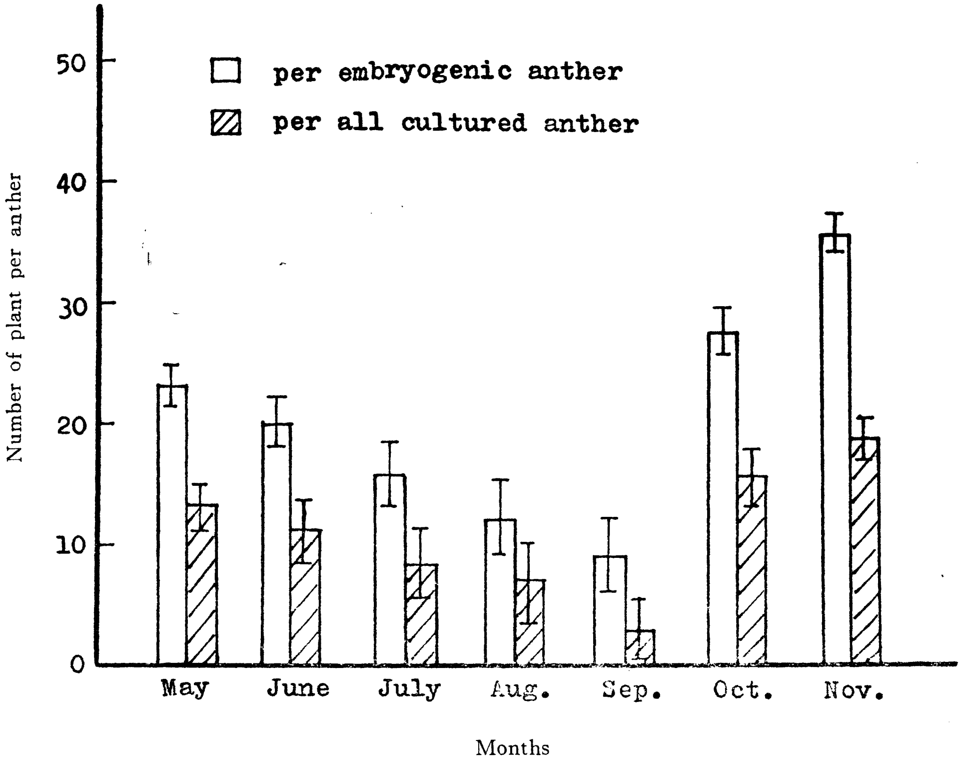

圖 1. 生長於 Hoagland 基本培養液下之母體植物，不同月份之花葯培養所得平均植物體數。

Fig. 1. The number of plants per cultured anther taken from donor plants at different month (donor plants grown in basic Hoagland solution).

花葯只產生 1～2 株植物體。從 5 到11月的七個月中，以11月較低溫度時（日夜平均溫度約 18°20～°C）花葯培養所得之植物體最多。相同的地點（加州大學 Riverside 分校）Madrigal 及 Murashige 二氏從事菸草花葯的週年培養，亦認爲夏季月份所得之花葯，植物體形成率最差（私人

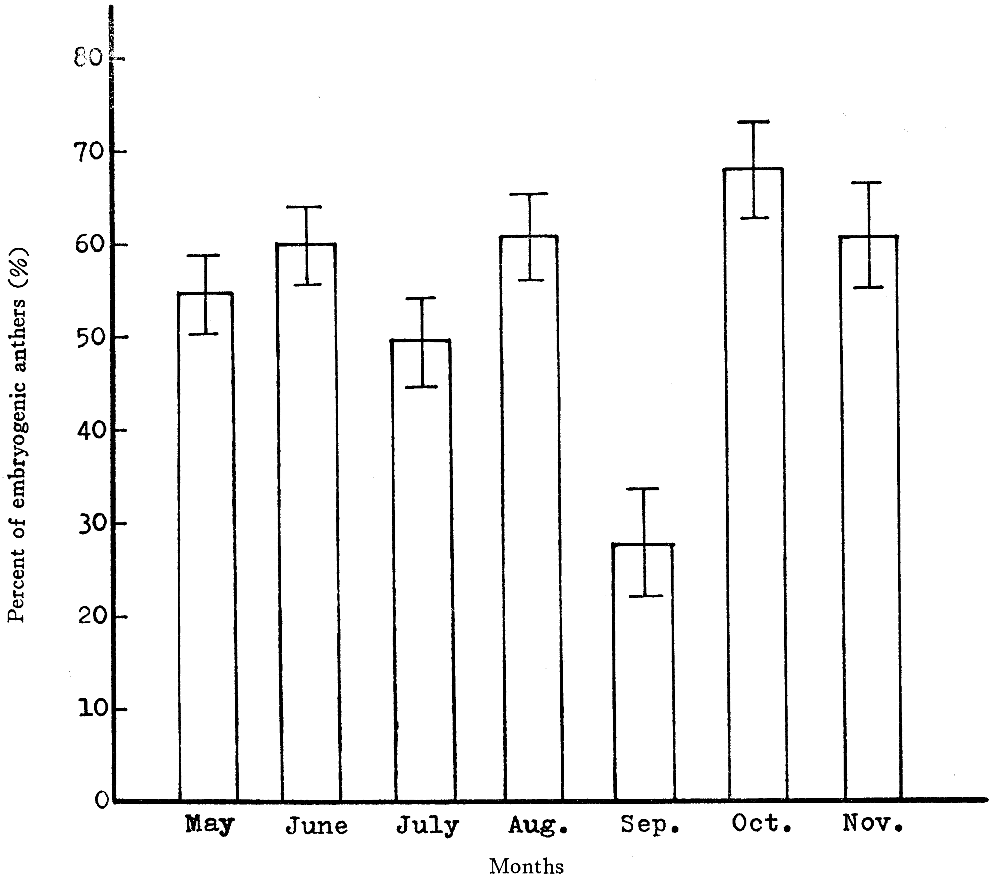

圖 2. 生長於 Hoagland 基本培養液下之母體植物，不同月份花葯培養產生植物體之平均花葯數。
Fig. 2. The percentage of embryogenic anthers of cultured anther taken from donor plants at different month (donor plants grown in basic Hoagland solution).

連繫）；氣象資料顯示此地區之溫室，因地處沙漠邊緣，夏季 8～9 月份中午時之溫度，雖有冷氣調節，但仍可高達 40°C 左右，尤其靠近溫室玻璃頂之地更高，所以推測高溫可能是造成此時期花葯培養植物體形成低下的主要原因。再者，夏季時的長日，此地區可達 16 小時左右，Dunwell [1] 曾報導母體植物生長於 16 小時日長下之菸草花葯培養，其 bud productivity（每個花蕾所生之植物體數）爲 8.1，而相同光强 8 小時短日處理之母株，其 bud productivity 却可高達 43.4 ，所以日長可能是此時期花葯培養反應不良的另一原因。

利用醋洋紅壓潰法對每個花蕾中之一個花葯進行觀察時，發現夏季月份所生之花葯，常有許多不含小胞子的不正常花葯產生，其比例如表 3 所示：

表 3. 7 -11 月份生長下之菸草母體植物所含不正常花葯數的百分比。

Table 3. The precentage of flower buds with abnormal anthers (no microspore) taken from donor plants at July to November.

Flowering Month	mM Nitrogen in Culture Solution	Number of Flower Buds Inspected	Abnormal Flower Buds		
			Number	%	95%Cl[a]
July	4.5	158	25	15.8	10–23
	15.0	203	6	3.0	1–6
	45.0	180	24	13.3	8–19
August	4.5	220	87	39.5	3347
	15.0	164	9	5.5	3–10
	45.0	144	44	30.6	23–40
September	4.5	240	67	27.9	22–3
	15.0	301	28	9.3	6–13
	45.0	270	61	22.6	18–28
October	4.5	232	2	1.0	0–4
	15.0	288	0	0.0	0–1
	45.0	264	1	0.4	0–2
November	4.5	196	0	0.0	0–2
	15.0	233	0	0.0	0–1
	45.0	2.07	0	0.0	0–2

a. 95% confidence limit

表 3 資料顯示夏季月份生長的菸草，氮素量過多或不足均可促進不含小胞子的不正常花葯大量產生，這種情形以 8 - 9 月份最嚴重，7 月份次之，10月份已極少，11 月份則不管氮素多寡，所生之花葯均含有小胞子，5 、6 月份資料不全故未列上。

高溫配合氮素量供給的不平衡，亦可使每個花蕾內所含有的花葯數產生極大的變化，如表 4 所示：

表 4. 9 月份生長的母體植物，每個花蕾內花葯數之變異情形

Table 4. The variation of anther number in flower buds taken from donor plants flowered in September.

mM Nitrogen in Culture Solution	Number of Flower Buds Inspected	No of Flower buds Contained 3 Anthers			No. of Flower Buds Contained 4 Anthers			No. of Flower Buds Contained 5 Anthers			No. of Flower Buds Contained 6 Anthers		
		No.	%	95%Cl[a]	No.	%	95%Cl[a]	No.	%	95%Cl[a]	No.	%	95%Cl[a]
4.5	241	1	0.4	0–2	70	29.1	23–35	170	70.5	65–77			
15.0	301				43	14.3	10–19	258	85.7	81–90			
45.0	270				47	17.4	12–22	210	77.8	72–83	13	4.8	3–8

a. 95% Confidence limlt

表 4 的資料顯示夏季高溫，長日缺氮生長下的菸草花蕾，有形成較少花葯的趨勢，例如一般正常的花蕾含有 5 個花葯，而低氮素量生長下，則有 29.1 %只含 4 個花葯的花蕾，正常花蕾數只佔 70.5 %，更有 0.4%的花蕾只含 3 個花葯的。高溫長日多氮則反而有使每一花蕾產生多葯的趨勢；例如過量氮素(45 mM)下之花蕾，有 4.8 %含有 6 個花葯，這種多葯的花蕾在 4.5及 15 mM 氮素下全無發生，但過量氮素亦可產生只含 4 個花葯的不正常花蕾 (17.4%) 。醋洋紅壓潰法檢察得知每個花蕾的花葯數和不含小胞子的不正常花葯間並無相關關係；即含有 4 或 6 個花葯的花蕾，其花葯內的小胞子常是十分正常，而含有 5 個花葯的正常花蕾 ，其所生花葯的小胞子卻常有不正常的情形發生。 10 月份所生過多或不足花葯的花蕾數很少，只佔 2 % 而已 ，可能的原因爲溫度下降及日照時間的縮短，11月份則幾全爲正常之花蕾。

將正常的花葯及不含有小胞子之不正常花葯，以石蠟切片法觀察其內部構造時，發現正常小胞子的分裂及不正常花葯小胞子囊異常的情形如圖 3 及圖 4 。

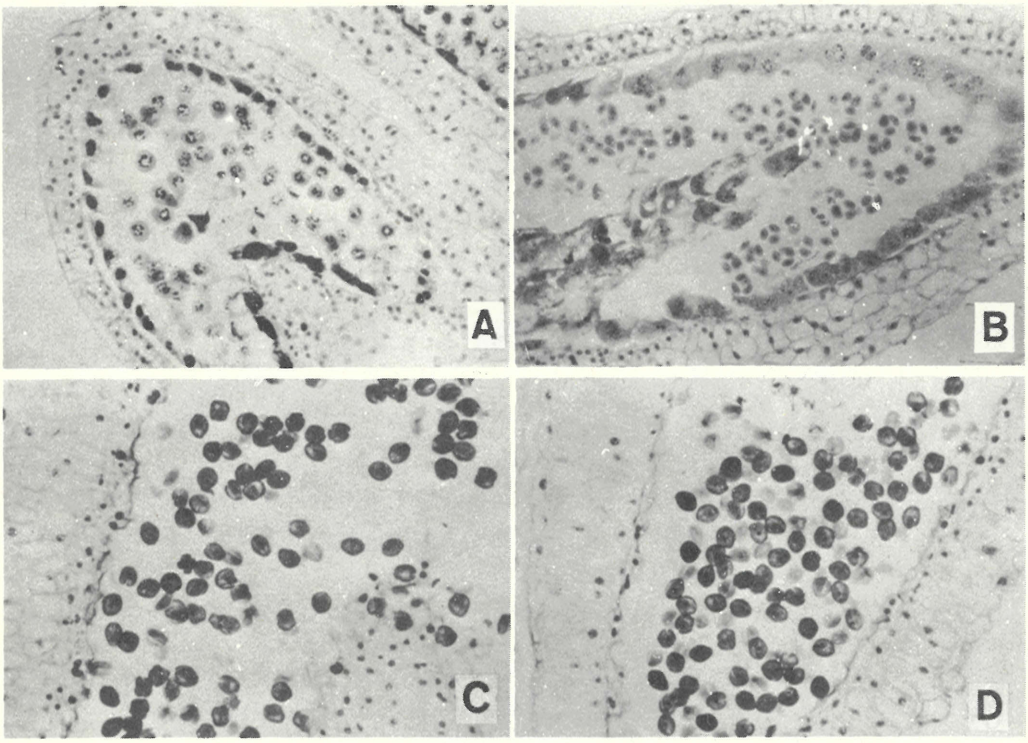

圖 3. 菸草不同發育時期的正常小胞子。

Fig. 3. The normal microspores of *N. tabacum* at different developmental stages. A. meiosis stage B. tetrad stage C. first pollen mitosis stage D. early binucleate stage. Magnification : 55OX

圖 3 顯示正常的小胞子發育，在減數分裂期花葯壁最內層之 tapetum 層發育良好，其細胞核極大(fig. 3-A) ，四分子期則 tapetum 層位於緊貼花葯壁的內層，呈單層整齊排列(fig. 3-B)，第一次有絲分裂期 tapetum 層開始分解，以供給小胞子發育的養份 (Maheshwari, 1950) [8] ，至雙核期則 tapetum 只剩薄薄一層不十分明顯的細胞(fig. 3-D)，小胞子在全發育期中可見核之分裂，小胞子形成後更可見單一之獨立個體 。而圖 4 所示之不正常花葯則幾乎未見小胞子之分裂，花粉囊內幾

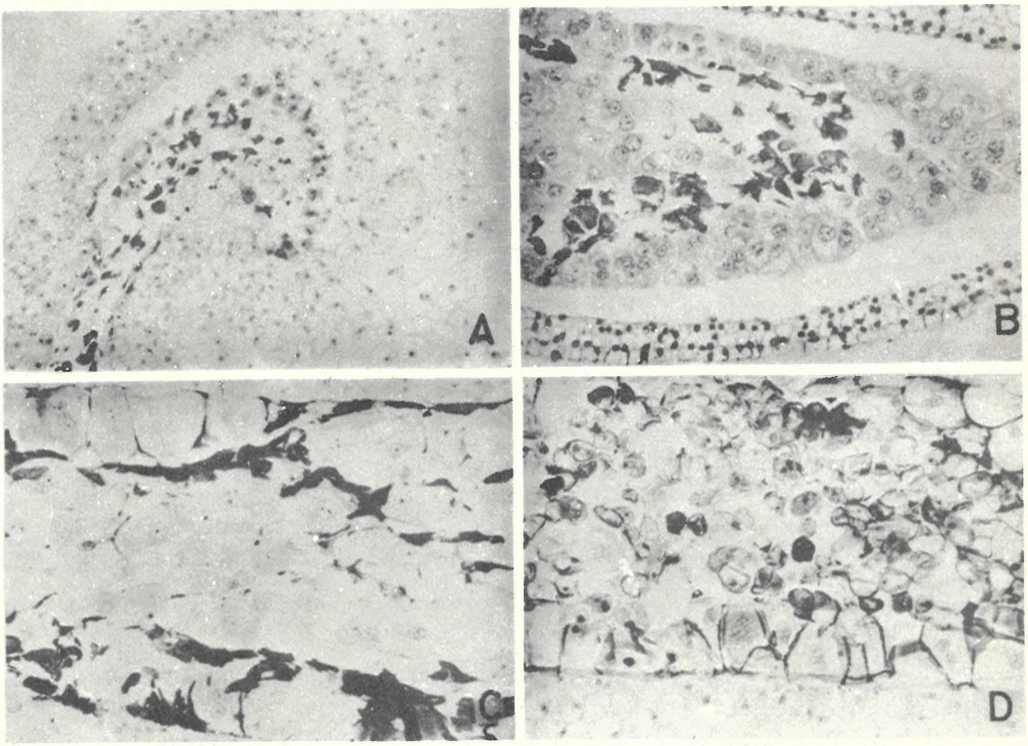

圖 4. 菸草不同發育時期的不正常小胞子。

Fig. 4. The abnormal microspores of *N. tabacum* at different developmental stages. A. meiosis stage B. tetrad stage C. first pollen mitosis stage D. another type of abnormal anther at first pollen mitosis stage. Magnification : 550X

乎全爲不正常分裂之 tapetum 細胞所佔滿，四分子期之花粉囊內 tapetum 層厚而遠離花葯壁(fig. 4-B)，擬似 tapetum 細胞的細胞間隙間充滿着染色成黑色之不明物質 (fig. 4-C)，有些花粉囊內的小胞子變化爲擬似石細胞狀之形體 (fig. 4-D)，十分明顯的，若取材自這些不正常的花葯培養，植物體的產生當屬不可能。

Sunderland [11] 氏曾指出，利用花萼、花冠長度的比例做爲小胞子不同發育時期的指標，常會因母體植物開花的早晚而產生極大的偏差； Sunderland, Collins 及 Dunwell [12] 等氏亦認爲即使相同植物的每個個體間，其開花生理也都會有不同程度的差異，所以利用花萼、花冠之比值做爲小胞子發育時期的指標，除了容易發生檢定時期不精確外，亦可能將含有不正常小胞子的花葯取之培養，因而造成單倍體形成的低下；本試驗雖對每個花蕾中的五個花葯取其中之一以醋洋紅壓潰法檢查其時期，但相信也會有每個花蕾中的五個花葯各有發育不同的現象。Muraoka 及 Ohori [9]，Kasperbauer [7] 等氏曾報導菸草。母體植物生長於 8 小時短日， 18°C 恆溫下，花的形成最快且發育得最完全；Dunwell [1] 也曾報導生長於 8 小時短日强光 (14,000 lux), 20°C 下之菸草，其花葯培養而導致 anther productivity (每個花葯所形成的植物體數)最高；他解釋由於溫度及日長效果交互的作用，花葯壁所生荷爾蒙處於最有利於胚發育的平衡狀態，是此種處理菸草花葯培養易於誘致植物體形成的主要原因，本試驗中，夏季月份所栽培之菸草，由於花蕾、花葯及小胞子之異常，而導致培養後植物體形成能力之低下，即可能與溫度及日照二個重要因子有關。

參 考 文 獻

1. Dunwell, J. M. 1976. A comparative study of environmental and developmental factors which influence embryo induction and growth in cultured anther of *Nicotiana tabacum*. Environ. Exp. Bot. 16 : 109-118.
2. Engvild, K. C., I. Linde-Laurson and A. Lundqvist. 1972. Anther cultures of *Datura innoxia* : flower bud stage and embryoid level of ploidy. Hereditas 72 : 331-332.
3. Guha, S. and S. C. Maheshwari. 1964. In vitro production of embryos from anthers of *Datura*. Nature 204 : 497.
4. Guha, S. and S. C. Maheshwari. 1966. Cell division and differentiation of embryos in the pollen grains of *Datura* in vitro. Nature 5059 : 97-98.
5. Guha, S. and S. C. Maheshwari. 1967. Development of embryoids from pollen grains of *Datura* in vitro. Panchanan Maheshwari Memorial : 454-461.
6. Hoagland, D. R. and D. I. Arnon. 1938. The water culture method for growing plants material soil. UC Agri. Exp. Sta. Circular 347 : 1-39.
7. Kasperbauer, M. J. 1970. Photo-and thermo-control of flowering in tobacco(*Nicotiana tabacum* L.). Agron. J. 62 : 825-827.
8. Maheshwari, P. 1950. An introduction to the embryology of angiosperms. pp : 28-53. New York-Toronto London, McGraw-Hill.
9. Muraoka, Y. and K. Ohori. 1956. Developmental responses of tobacco plants under various temperatures and photoperiods. Proc. Crop. Sci. Soc. Japan 25 : 104-106.
10. Murashige, T. and F. Skoog. 1962. A revised medium for rapid growth and bio-assays with tobacco tissue culture. Physiol. Plant. 15 : 473-487.
11. Sunderland, N. 1974. Anther culture as a means of haploid induction. In : Kasha, K. J. (ed.)Haploids in higher plants : Advances and potential. pp : 91-122. Guelph, Uuiv. Guelph.
12. Sunderland, N., G. B. Collins and J. M. Dunwell. 1974. The role of nuclear fusion in pollen embryogenesis of *Datura innoxia* Mill. Planta 117 : 227-241.
13. Tsai, S. C. and M. H. Lin. 1977. Production of rice plantlets by anther culture. J. Agri. Res. China 26 (2) : 100-112.
14. Tsay. H. S. 1980. Strong acid treatment for making smears of tobacco microspores. J. Agri. Res. China 29 (2) : 103-106

Tobacco plants formation from anther culture as influenced by the mother plants grown under different seasons[1]

Hsin-Sheng Tsay[2]

Summary

The anthers of *N. tabacum* cv. Wisconsin 38 which were grown in Hoagland nutrient solution with different nitrogen levels were collected during the period of May-November. The collected anthers were cultured in Murashige and Skoog medium (1962) to produce haploid plants.

It was found that the embryogenic ability of anthers collected from the plants grown under the high temperature and long photoperiod condition (August-September) was extremely lower than those collected from the plants grown under the lower temperature and shorter photoperiod condition. In the hot summer season, the abnormal cells instead of functional microspores in pollen sacs as it was observed by the cytological study. The effects of high temperature and long photoperiod on the abnormal formation of microspore were considered to be the main reason why the embryogenic ability is so poor when this kinds of anthers were cultured in vitro.

Further, it was observed that the rate of abnormal anther was promoted when tobacco plants were cultured under either excess or deficient nitrogen supply condition. The low nitrogen supply resulted in fewer anther formation per flower bud and more anther formation per flower bud under the high nitrogen supply condition as compared with controls.

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葡萄組織培養之研究

環境因子對葡萄癒傷組織生長及分化的影響[1]

賴 本 智[2]　　易 希 道[3]

摘要：巨峰葡萄 (*Vitis viniferal* L. CVS. Sentenial X 石原早生) 植株的莖段，葉片及果肉培養於含 NAA 0.1mg/l、Kinetin 0.2 mg/l 及 15% (w/v)coconut milk. 的 Gamborg 和 Eveleigh 基本培養基中可誘導形成癒傷組織，經上述培養基繼代培養得多量癒傷組織，以進行各種環境因子對其生長及分化影響的測定。經研究顯示，莖段癒傷組織生長最適的 PH 值爲 5.6。光線的强弱能影響癒傷組織的生長，果肉癒傷組織適合生長於 750 到 3,000 lux 之間的光强，光强超過 4,500 lux 或在黑暗下培養均不利於癒傷組織的生長。在各種光質中以藍光最適於果肉癒傷組織的生長，黃光、紅光次之，綠光較差，固體培養基培養之葉片與莖段癒傷組織均可形成鳥巢狀的維管束環節 (nest-like Vascular nodule)，其內部具有許多木質化的細胞或管形細胞，外部則具有許多類似形成層細胞 (Cambium-like cells) 的環狀結構，由此類形成層結構，可再進一步分化形成根。而葉片癒傷組織外部的細胞也可分化形成芽原體 (shoot primordia) 之構造。果肉癒傷組織在任何培養情形下，均無分化的細胞。液體震盪培養下的葉片和莖段癒傷組織其細胞僅可分化形成似根之多極性 (poly-arch) 維管組織型 (Vascular pattern)，無再進一步分化的現象。而果肉癒傷組織則均呈游離的細胞或細胞羣，沒有癒傷組織塊的形成，也無分化的現象。液體震盪培養雖能誘發葉片及莖段癒傷組織的特化，唯較固體培養者差。

培養基的物理條件如酸鹼度 (pH)、固態及液態培養基通常爲造成癒傷組織生長差異的主要原因[(2,10,19)]，Hildebrandt 等人報導 pH 5.6 時，最適合菸草莖段癒傷組織的生長，過高或過低均可能產生不利之作用[(14)]。蔡氏報導甘藷花葯癒傷組織生長最適之 pH 值以 6.5 爲最佳[(2)]。液體震盪培養不僅可增進極易產生褐化物質(如酚酞類或過氧化酵素等)的培養材料生長或增殖，而且更適於單細胞之大量培養[(3,19)]。環境因子中如光線的質和量亦爲左右癒傷組織生長及分化的主要因子[(6,10,24)]，癒傷組織培養早期，因可利用培養基中的碳源行異營生長，對於光線的需求較不敏感[(18,28)]；但到培養後期，光線不僅能影響到癒傷組織的生長，也可參與其形態發生，尤其是芽之誘發[(24)]及根的形成[(10)]，光照太强或太弱均不利於癒傷組織的生長，Weis 等[(24)]報導不同的光質如紅、黃、藍、綠光等，對於菸草髓部癒傷組織的生長及分化有很密切的關係存在。故適度的光照及正確的光質常爲癒傷組織生長及分化所必需。

上述培養基的物理條件及環境因子對葡萄癒傷組織的影響鮮爲人知，本文即針對培養基酸鹼度，固體或液體以及環境因子中之光量與光質等因子對葡萄癒傷組織之作用詳加探討。

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料料與方法

將巨峰葡萄植株新芽上之莖段、葉片及果肉培養於含 NAA 0.1 mg/l、Kinetin 0.2 mg/l 及 15% (w/v) 椰子胚乳液之 Gamborg 和 Eveleigh (1968) 基本培養基上，於溫度 25±1°C，日光燈源的光度為 750～1,000 lux，光週期 12 小時的培養環境下所誘導的癒傷組織，以上述培養條件繼代培養所得之大量癒傷組織為材料，並以每一處理重覆30次所得之平均值計算，探討下列各種環境因子的影響。

一、酸鹼度對癒傷組織生長的影響

秤取 100 mg 的莖段癒傷組織，移入消毒前酸鹼度分別為 4.4，4.8，5.2，5.6，6.0，6.4 及6.8 的基本培養基中，培養 4 週後測其鮮重及乾重（在 60°C 中烘乾24小時後測得。）

二、光對癒傷組織生長的影響

（一）光質：秤取 40 mg 的果肉癒傷組織，移入含基本培養基的試管中，置於約 2,500 lux 之白色日光燈下，其燈管外包以一層賽璐玢色紙 (Cellophane paper) ，有紅色、綠色、藍色、黃色四種，其中黃色包以二層，另包以黑色厚紙者作為對照處理 [1]。經 5 週培養後測定其鮮重及乾重。

（二）光度：秤取 40 mg 的果肉癒傷組織，移入基本培養基中，培養於光度分別為 4,500，3,000，1,500，750 及 250 lux 的培養架上。另以包黑色厚紙者為對照處理，經培養 5 週後測其鮮重

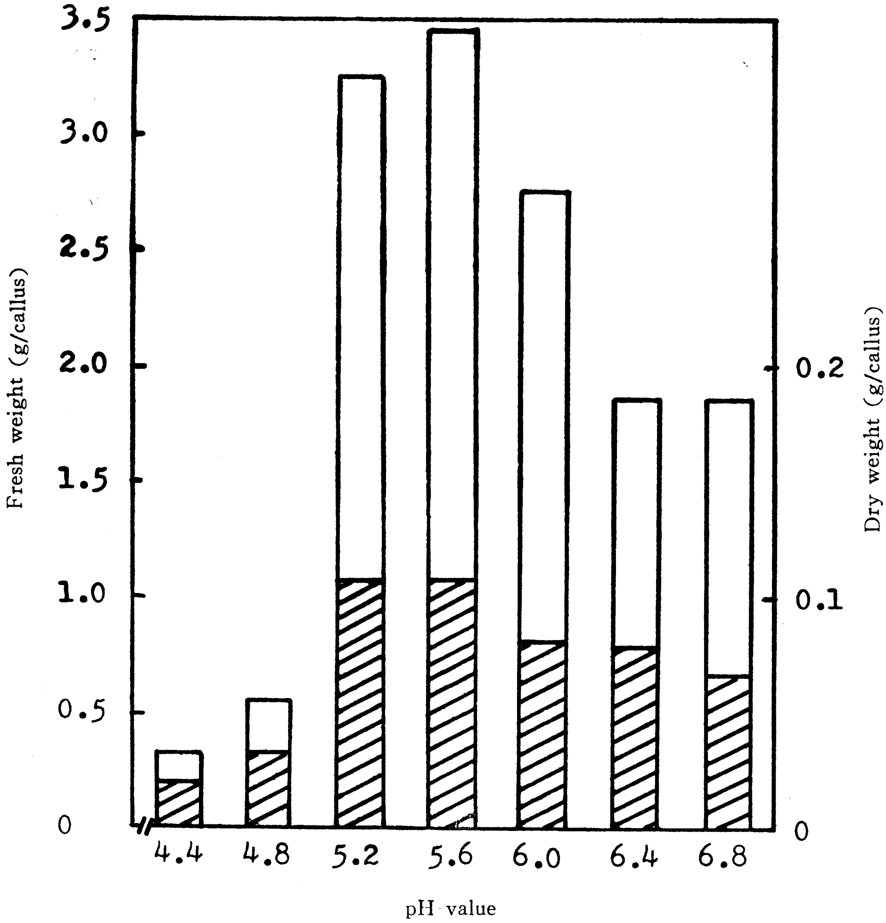

圖 1. 培養基酸鹼度對葡萄莖段癒傷組織生長之影響。

Fig. 1. Effect of pH value on the growth of grape stem callus after 4 weeks in culture.

及乾重。

三、液體震盪培養對癒傷組織生長及分化的影響

將固體培養基培養所得之癒傷組織切取約 2 g 大小，移至僅不含洋菜之固體基本培養基中，於每分鐘震盪 70 次之震盪器上培養，5 週後以 FAA 固定做成石臘切片再和固體培養所得之癒傷組織切片加以比較，以了解各種不同器官來源的癒傷組織生長情形及其分化程度。

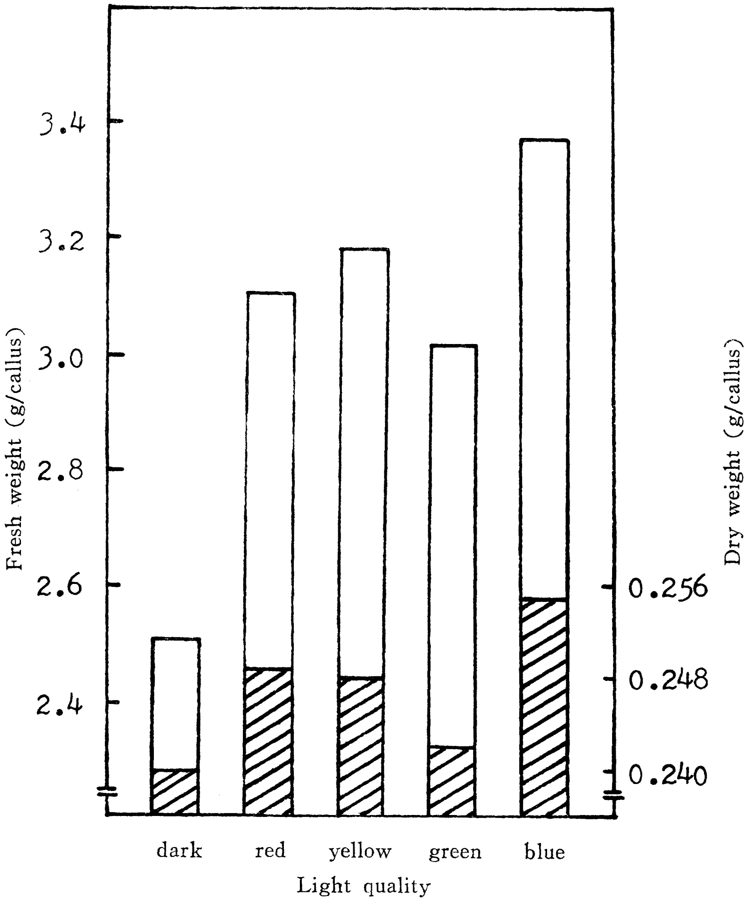

圖 2. 光質對果肉癒傷組織生長的影響。

Fig. 2. Effect of light quality on the growth of grape fruit callus after 5 weeks in culture.

結果與討論

一、癒傷組織生長的最適酸鹼度

在以莖段癒傷組織所做的培養試驗中，發現 pH 5.6 時，鮮重增加最多，5.2次之，但二者乾重差異不顯著；其適應的酸鹼度爲 5.2～6.0 之間（圖 1），此與 Hildebrandt 等氏[13,14] 利用向日葵和菸草的莖段及 Anstis [4] 利用馬鈴薯塊莖等的癒傷組織所做酸鹼度的試驗結果相一致 [4,13,14]，但蔡氏[2] 等報導甘藷花藥癒傷組織生長以 pH 6.5 爲最佳，此等差異可能是所用的材料種類不同之故。一般癒傷組織的生長均較適合於稍酸性培養基。可能的原因是在微酸時，大部鹽類保持在可溶性的有效狀態，以供癒傷組織的吸收與利用[20]。當pH 值低於 5. 0時，癒傷組織的生長顯著減少，可

能係酸性過低促使某些成份如噻胺 (thiamine) 於高溫高壓消毒時，發生分解之故[4]；而 pH 值過高却會影響某些激素的吸收[4]，故過高或過低的 pH 值均不利於癒傷組織的生長。

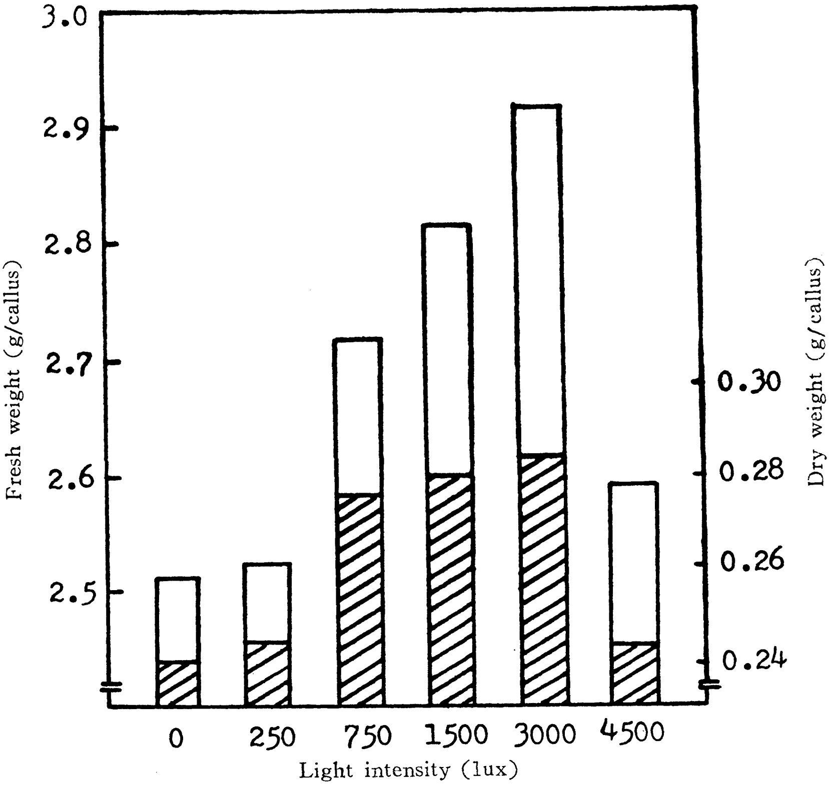

圖 3. 光度對果肉癒傷組織生長的影響。

Fig. 3. Effect of light intensity on the growth of grape fruit callus after 5 weeks in culture.

二、光對癒傷組織的影響

(一) 光質：由圖 2 可知，在各種光質測定中，果肉癒傷組織在藍色光下生長最佳，黃光次之，紅光又次之，綠光效果較差，黑暗下最差，此與 Weis 氏培養於草髓部細胞的結果相似[24]，雖然各種色紙透光率不一，光强或許有些差異，可能會影響部分結果的準確性，唯此項結果仍頗具參考價值。果肉癒傷組織在各種不同光質下也會形成許多葉綠素，其綠色程度亦以藍光、黃光及紅光下較佳，綠光下次之，黑暗下培養的癒傷組織呈現白色，不形成葉綠素，此乃因藍光和紅光爲主要的作用光譜，不論在光合作用[15]、葉綠素形成[5,16]、光形態發生[1,24]及光呼吸作用[17]方面均有重要的影響，藍光、紅光不僅可增加光合作用能力，而且有助於葉綠素形成，提高綠色度。綠光常不爲葉綠素所吸收，不能加以有效利用[24]，故綠光下癒傷組織的鮮重、乾重及綠色度均較上述者爲差。黑暗下培養因無光源可資利用，癒傷組織不含葉綠素，只能行異營生長，後期生長最差。

(二) 光度：在不同光度下培養的果肉癒傷組織，由圖 3 可知，以 3,000 lux 的光度下生長最佳，1,500 lux 次之，光度愈弱生長愈差，黑暗時生長最慢。光度過强 (4,500 lux) 也有抑制生長的現象，唯光度愈强其癒傷組織的綠色度愈佳。癒傷組織早期的生長因可利用培養基中的碳源，故對於光線的需求較不敏感[2,8,18]。但到後期光線能影響形態發生，尤其是芽之誘發[24]，故光線對於完整植株的生長是絕對必需的條件；Weis 和 Jaffe[24] 發現於草髓部的癒傷組織在藍光下可促進芽體的形成，一般白光下又比黑暗下更易形成芽體。光線也能影響根的形成，Gautheret 報導

Helianthus tuberosus 塊根癒傷組織，在 Auxin 存在下， 5,000 lux 光强及每日 12 小時之光期時，可促進最多根數的形成， 同時知其作用主要發生在形成層 (Cambium) 區域，而黑暗下雖然 Auxin 也存在時，則會減少根形成的能力 [10] 。Capite [6] 發現胡蘿蔔根部癒傷組織 2,800 lux 的光

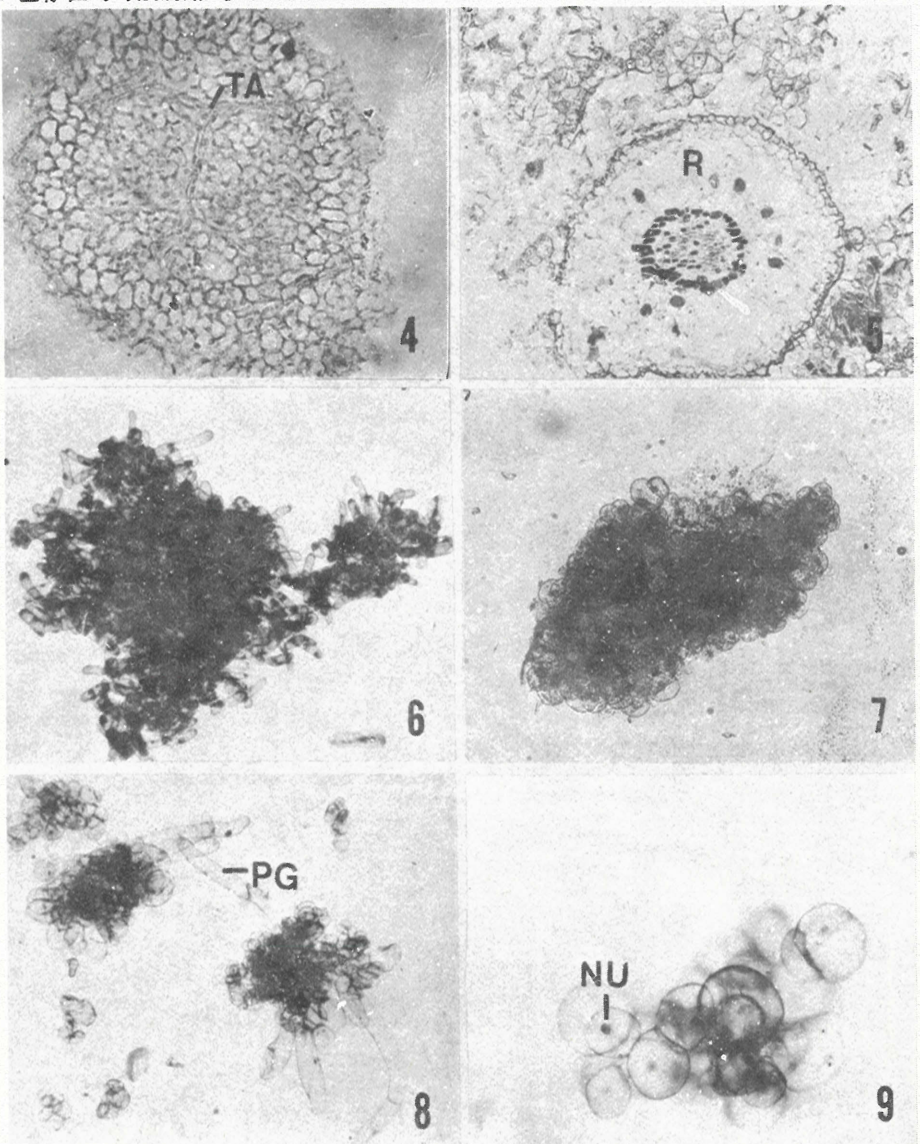

圖 4. 葉片癒傷組織於液體培養時，內部分化為似三極性的根部維管組織。**Fig. 4.** A tri-arch root vascular bundle(TA)initiated from leaf callus cultured in liquid medium.

圖 5. 固體培養時，由葉片癒傷組織內部細胞分化而成根的橫切面。**Fig. 5.** A cross section of root (R) initiated from leaf callus cultured on solid medium.

圖 6. 葉片癒傷組織於液體培養時，顯示分離的細胞羣，細胞為長形。 **Fig. 6.** Leaf callus showing cell colonies which contain long cells in liquid culture.

圖 7. 莖段癒傷組織於液體培養時，顯示分離的細胞羣和圓形細胞。**Fig. 7.** Stem callus showing cell colonies which contain round cells in liquid culture.

圖 8. 果肉癒傷組織於液體培養時，分離出的各種細胞羣，有些細胞呈極性生長。**Fig. 8.** Cell colonies of fruit callus in liquid culture. Some cells showed polar growth (PG).

圖 9. 生長中的果肉細胞羣，具圓形細胞和明顯的細胞核。**Fig. 9.** The fruit cell colonies which contain round cells is showed the nucleus (NU).

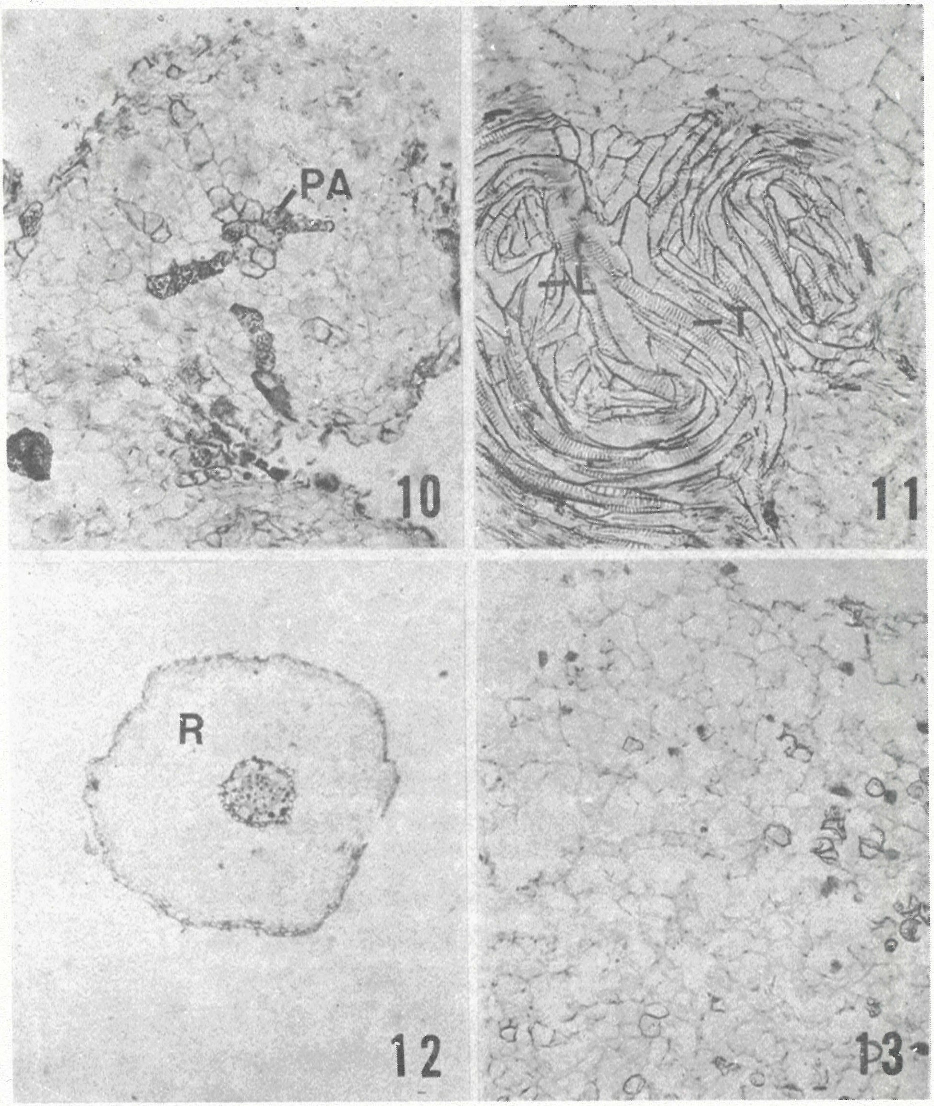

圖 10. 莖段癒傷組織於液體培養時，分化成多極性的根部維管組織。Fig. 10. A poly-arch root vascular bundle (PA) initiated from stem callus cultured in liquid medium.

圖 11. 莖段癒傷組織於液體培養時，內部細胞分化成維管束環節，具有木質化細胞和管形細胞。Fig. 11. The formation of vascular nodule which enclosed lignified cells (L) and tracheid cells (T) initiated from inside of stem callus cultured in liquid medium.

圖 12. 固體培養時，由莖段癒傷組織細胞分裂突出形成根的橫切面。Fig. 12. A cross section of root (R) initiated from stem callus cultured on solid medium.

圖 13. 果肉癒傷組織於固體培養時，細胞無分化現象。Fig. 13. A cross section of fruit callus without any differentiation cultured on solid medium.

強比 1,200 或 6,000 lux 生長為佳。故光線的強弱會影響到癒傷組織的生長，本試驗所做的葡萄果肉癒傷組織在光線過低 (250 lux) 或黑暗下，癒傷組織呈白色，生長效果較差，與王氏 [1] 在新美娘蘭 (Cymbidium) 癒傷組織培養所得的結果相一致。

三、液體震盪培養對癒傷組織生長及分化的影響

(一) 葉片癒傷組織：葉片癒傷組織經液體震盪培養一個月後，組織增大，內部大多為薄壁細胞

，有些特化形成維管組織，或分化形成多極性（poly-arch）的根部維管組織型（Vascular Pattern）（圖4），唯其分化程度較固體培養（圖5）者爲差，沒有根及維管束環節（Vascular nodule）的形成，此與廖氏[3]研究大岩桐葉片癒傷組織在液態震盪培養下仍有胚狀體之形成迥異，可能係因植物特性不一而影響分化能力[23]。又葉片癒傷組織可分離出具有多細胞組成的細胞羣（multi cellular clumps），此等細胞皆由懸浮細胞羣的表面分裂形成，與 Durzan[7] 等氏研究白針樅的雌性配子體癒傷組織在液體培養的結果相似，只有少數細胞呈游離方式存在，而且所有分離的細胞羣或單細胞均呈長形（圖6），異於莖段及果肉癒傷組織於液體培養所得之圓形細胞（圖7、8、9），可能是不同部位的細胞來源所致。

（二）莖段癒傷組織：經液體震盪培養後，質地較爲緻密，部分內部細胞分化形成多極性的根部維管組織型（圖10），或特化形成鳥巢狀的維管組織，其內部具有許多特化的本質化細胞（lignified elements）和管形細胞（tracheid elements）（圖 11），此與 Steward[23] 等氏培養胡蘿蔔根部癒傷組織的細胞結果相同。組織逐漸增大，極少數分離成具有許多圓形細胞的細胞羣（圖7）。液體震盪培養之莖段癒傷組織，較固體培養之分化能力差（圖12），唯仍較果肉癒傷組織在液體培養之分化能力爲佳（圖13）。

（三）果肉癒傷組織：經液體震盪培養後，質地鬆軟極易分散（圖13），分離出許多不等細胞數目的細胞羣（multiple cellular clumps）及少數的單細胞，此等細胞分裂迅速，大部呈圓球形（圖8、9），與 Hawker 等氏[12] 所做的葡萄果肉癒傷組織的液體震盪培養結果相一致。少數細胞可自各種細胞羣表面或自身經過多次分裂，形成許多極性生長的長形細胞羣（圖8），極少數細胞有縱裂的現象，此種分裂方式頗似 Halperin 和 Wetherell 所做的胡蘿蔔根部癒傷組織在液體震盪培養下的細胞分裂情形[11]。唯葡萄果肉癒傷組織不能形成絲狀胚（filamentous embryos），以致未能再進一步分化[11]，在固體培養下之葡萄果肉癒傷組織也無任何分化現象，這種結果與大多數植物的果肉癒傷組織不易分化的結果相同[22]。但極少數種類的果肉細胞仍具有分化的全能性（totipotency），如酪梨（Avocado）的外果皮（Pericarp）及中果皮（mesocarp）癒傷組織經培養一年後仍可分化形成根[22]；南瓜（*Zucchini squash*）的外果皮癒傷組織經培養後可再分化形成小植株[21]。故癒傷組織的分化能力，不僅受到來源、位置和器官的影響，而且也受到植物種類的影響[11,22,23]。

由以上探討得知葡萄癒傷組織最適的生長 pH 值爲 5.6，最適的光質和光度分別爲藍色光及 3,000 lux）固體培養基又比液體震盪培養基適於誘導癒傷組織的分化。

引 用 文 獻

1. 王博仁・1973・高等植物組織的逆分化和再分化現象。生長與分化專題研討會講稿集：87-104。
2. 蔡新聲、林正義・1973・培養基成份、蔗糖濃度、pH 值、溫度及光線對甘藷花葯 Callus 生長的影響。中華農學會報 新 82：30-41。
3. 廖松淵、易希道・1974・組織培養的條件影響大岩桐癒傷組織形成和器官發育。中興大學植物研究所碩士論文。
4. Anstis, P. J. P. and D. H. Northcote. 1973. The initiation, growth, and characteristics of a tissue culture from potato tubers. J. Exp. Bot. 24(79):425-441.
5. Anstis, P. J. P. and D. H. Northcote. 1974. Chlorophyll accumulation by callus tissue of *Glycine max*. Planta (Berl.) 116 : 105-108.
6. Capite. L. 1975. Action of light and temperature on growth of plant tissue in vitro. Amer. J. Bot. 42 (10):869-873.
7. Durzan, D. J., S. C. Chafe and S. M. Lopushanski. 1973. Effects of environmental change on sugars, tannins, and organized growth in cell suspension cultures of white spruce. Planta (Berl.) 113:241-249.

8. Fraser, R. S. S., U. E. Loening and M. M. Yeomen. 1967. Effect of cell division in plant tissue culture. Nature 215:875.

9. Gamborg, O. L. and D. E. Eveleigh. 1968. Culture methods and detection of glucanases in suspen -sion cultures of wheat and barley. Can . J. Biochem. 46:417-421.

10. Gautheret, R . J. 1969. Inverstigations on the root formation in the tissue of *Helianthus tuberosus* cultured in vitro. Amer. J. Bot. 56:702-717.

11. Halperin, W. and D. F. Wetherell. 1964. Adventive embryo in tissue cultures of the wild carrot, *Daucus carota*. Amer. J. Bot. 51(3):274-283.

12. Hawer, J. S., W. J. S. Downton, D. Wiskich and M. G. Mullins. 1973. Callus and cell culture from grape berries. Hort. Sci. 8(5):398-399.

13. Hildebrandt, A. C., A. J. Biker and B. M. Duggar. 1945. Growth in vitro of excised tobacco and sunflower tissue with different temperatures hydrogen-ion concentrations and amounts of sugar. Amer. J. Bot. 32:357-361.

14. Hildebrandt, A. C., A. J. Biker and B. M. Duggar. 1946b. The influence of the composition of the medium on growth in vitro of excised tobacco and sunflower tissue cultures. Amer. J. Bot. 33:591-597.

15. Hoover, W. H. 1937. The dependence of carbon dioxide assimilation in a higher plant on wave length of radiation. Smithsonian Inst. Misc. Collections 95:1-13.

16. Koski, V. M., C. S. Frensh and J. H. C. Smith. 1951. The action spectrum for the transformation of protochlorophyll chlorophyll a. Arch. Biochem. Biophys. 31:1-17.

17. Kowallik, W. and H. Gaffron. 1967. Enhancement of respiration and fermentation in algae by blue light. Nature 215:138-144.

18. Murashige, T. 1974. Plant propagation through tissue culture. Ann. Rev. Plant physiol. 25:135-166.

19. Murashige, T. 1977. Manipulation of organ initiation in plant tissue cultures. Bot. Bull. Academia Sinica 18:1-24.

20. Nitsch, J. P. and C. Nitsch. 1956. Auxin-dependent growth of excised *Helianthus tuberosus* tissues. Amer. J. Bot. 43:839-851.

21. Schroeder, C. A. 1968. Adventive embryogenesis in fruit pericarp tissue in vitro. Bot. Gaz. 129(4): 374-376.

22. Schroeder, C. A., E . Kay and L. H. Davis. 1962. Totipotency of cells from fruit pericarp tissue in vitro. Science 138:595-596.

23. Steward, F. C., M. O. Mapes and K. Mears. 1958. Growth and organized freely suspended cells. Amer. J. Bot. 45(10):705-708.

24. Weis, J. S. and M. J. Jaffe. 1969. Photoenhancement by blue light of organogenesis in tobacco pith cultures. Physiol. Plant. 22:171-176.

Studies on tissue culture of grape (*Vitis viniferal* L.)

Influence of environmental factors on the growth and differentiation of grape callus. [1]

Pen-Chih Lai and Shi-Tao Yie[2]

Summary

Callus from grape stem, leaf and fruit sections were induced in modified Gamborg and Eveleigh (1968) medium containing 0.1 mg/1 of NAA, 0.2 mg/1 of kinetin and 15% (w/v) of coconut milk. They were then subcultultured for testing the influence of medium pH and light factors on the callus growth.

Optimum pH of medium for the growth of stem callus was found to be 5.6 followed by 5.2. Values above 6.4 or below 4.8 were not suitable for weight increases of callus in culture.

Fruit callus showed maximum growth when grown under blue light. Vigorous growth was also found under red and yellow light. However, growth was limited when callus were subjected to green light or darkness treatment. A light intensity of 3,000 lux was observed to give the hightest growth rate of fruit callus followed by 1,500 and 750 lux. Higher (4,500 lux) or lower (250 lux) light irradiation was less effective in increasing both the fresh and dry weight of callus.

Histological studies showed that when grown on solid medium, callus cells originated from stem sections could differentiate into nest-like vacsular bundles which contained many lignified cells and tracheid elements in the interior. Some nodulous structures could further differentiate into roots. Shoot primordia from the peripheral layer of leaf callus were also recorded. Fruit callus showed no ability of differentiation.

In liquid culture, the leaf and stem callus were able to form poly-arch vascular bund -les but showed no sign of organ differentiation. Fruit callus cultured in liquid resulted in many free cells or cell clonies without any specific differentiation. It was concluded that the regeneration ability was much higher when grown on solid than in liquid medium.

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收穫期對藺草產量與品質之影響[1]

韓　青　梅[2]

摘要：本試驗以中莖種藺草 Fs-72-p-8006 與細莖種藺草岡山3號爲材料，探討插植後180、195、210 與 225 日等四種收穫期對藺草產量與品質的影響，藉供栽培之參考。不同生育階段之調查顯示，藺草株高之增長速率以插植後 120~150 日間最高，90~120 日間次之，180 日後之生長已趨緩慢，二品種之表現相似。分蘖之增加亦以插植後 90~150 日間最爲迅速，細莖種岡山3號之分蘖數顯著高於中莖種 FS-72-P-8006。二品種之乾草產量及株高均以 210 日處理最高，中莖種之產量爲 13,580 kg/ha，有效莖長 127.5 cm，細莖種之產量爲 11,510 kg/ha，莖長 118.0 cm，均優於其他收穫期處理。藺草之髓徑與莖徑呈密切正相關，且無處理間差異，中莖種之平均莖徑爲 1.49 mm，髓徑爲 1.41 mm，細莖種則分別爲 1.06 與 1.00 mm。品種間比較，中莖種 FS-72-P-8006 之產量，品質及其他農藝性狀表現均較佳。試驗結果顯示，就產量與草長分級而言，中莖種 FS-72-P-8006 之收穫期以插植後 210 日，細莖種岡山3號則以 225 日最爲適宜。

藺草（*Juncus effusus* L. *var. decipiens* Buch）英名爲 mat rush，屬藺草科（*Juncaceae*）藺屬（*Juncus*），爲自生於溫帶山野溼地的宿根性草本植物。藺草之生長適溫雖介於20~25°C之間[1]，但僅中國、韓國及日本有經濟栽培，中尤以日本的栽培面積最廣，乾草消費量也最大。而藺草在日本之主要用途爲編織榻榻米、花蓆、草履、下駄表（wooden clogs）及各種手工藝品之材料。近十幾年來由於日本農村勞力不足，致使藺草栽培面積逐漸減少，然由於日本民族習性之偏好，對藺草之需要量仍很大，爲求供應無缺，遂由日商或各個財團逕向我國投資生產。

在日本，藺草之挿植時期一般爲每年之 10 月下旬至 12 月下旬，收穫適期則在 7 月中下旬[5]。據日本農林水產技術事務局報導，藺草之品質與其彈性有關，而收穫期之適當與否則爲決定彈性之重要因子[9]。西川[6]指出，藺草莖徑約達 2.5 mm 左右，莖色呈濃綠時，草莖內部充滿由星狀細胞所組成之柔軟的海綿狀組織（即髓部），此髓部之大小對藺草彈性之影響至鉅。中野則報告藺草收穫適期爲長草伸長至 105 cm 以上，草莖由濃綠變爲略帶黃色而富光澤，且莖具彈性時爲收穫適期[5]。日本岡山縣立農業試驗場報告，當地藺草若在 6 月收穫時；此時適爲草徑伸長最旺盛期，草莖短而品質差，而若在 8 月上旬收穫，則又因生育日數太長，先端發生枯黃現象，以致品質降低。亦即藺草之收穫適期影響品質甚鉅，早收或晚割均非所宜。

資料顯示[2]，在 1972 年本省藺草種植面積已達 438 ha，迄目前栽培面積則達 1000 ha，然因藺草在本省究爲一新興作物，目前尚缺少一完整之耕作方法可以遵行，故農民只得仿效日本之栽培方法行之。又因本省氣候及土壤等栽培環境與日本迥異，同時七月下旬正值二期水稻之挿秧期，僱工不易，加上此時適逢颱風雨季，對藺草之收穫調製甚感不便。本研究即針對此等問題，於 68 年進行

1. 臺灣省農業試驗所 研究報告 第932號。
2. 本所農藝系技佐。臺灣省 臺中縣 霧峰鄉。

本項研究，目的在探討本省藺草栽培之最適收穫期，俾便獲得最高之草莖收量及較理想之乾草品質，藉供今後是項耕作技術之參考。

材料與方法

以細莖種岡山 3 號及中莖種 FS-72-P-8006 爲供試材料，於 67 年 8 月上旬育苗，12 月 5 日移栽於臺灣省農業試驗所試驗田；行株距爲 20×20 cm，小區面積 4×1.6 m。收穫期分爲插植後180 、195 、210 及 225 天等 4 處理。試驗採用裂區設計，以收穫期爲主區，品種爲副區，重複 4 次。調查項目如下：(a) 生育期間之調查：於插植後 60、90、120 及 150 天調查其株高及分蘖數。(b) 收穫後之調查：按不同之收穫期分別收穫後行泥染、晒乾、再調查其莖徑、乾草重、株高、乾草分級、分級草量所佔百分率、草莖枯死率等。(c) 莖部橫切面髓部組織之顯微觀測：每處理隨機抽取中庸株 10 支分上、中、下、三部份各切取 5 cm長莖一段，以 F. A. A. 液固定三日後換以 70 % 酒精冷藏。用 Free hand section method 切片觀測之。每小區觀測 10 次，切片用 phloroglucin 染色，在顯微鏡下用測微計 (micrometer) 觀測髓部直徑之大小。

結果與討論

一、供試材料各性狀之變方分析

表 1 爲調查之 5 個主要農藝性狀的變方分析表。綜覽表 1 發現除分蘖數之區集效果顯著外，餘均不顯著，由此得知本試驗設計之土壤控制效果似尚得宜，資料應可信賴。而分蘖數有區集效果存在，似表示藺草分蘖數之表現較不穩定，比其他各性狀更易受微氣象所左右。亦即日後進行以探討藺草分蘖數爲主之試驗研究時，試驗環境之局部控制應更精確方可獲得正確之結果。而乾草產量、株高及分蘖數亦有因收穫期互異之差異存在，顯示收穫期之不同乃爲乾草產量發生變異之主因。至於調查 5 個主要農藝性狀之品種效果均顯著，顯示供試兩品種應屬兩個極端品種，其餘收穫期與品種之交感則僅分蘖數顯著。表示兩品種在不同收穫期之分蘖數表現並一致。

表 1. 不同收穫期多性狀之變方分析

Table 1. Analysis of variance for various characters at different harvesting date of mat rush.

S. O. V.	D. F.	Dry grass yield	Plant height	Tiller number	Stem diameter	Deat stem (%)
Block	3	ns	ns	**	ns	ns
Harvesting date (H)	3	**	*	**	ns	ns
Variety (V)	1	**	**	**	**	**
H×V	3	ns	ns	**	ns	ns

ns-nonsignificant

*-significantat 5% level

**-significantat 1% level

二、各性狀之表現

本研究各調查性狀經前綜合性之變方分析後，對各性狀之變異情形已有概括性之討論，今則進一步將各性狀在生育期之詳細變異情形示於表 2 。茲按不同的性狀分述如下：

表 2. 藺草不同生育期之各性狀表現

Table 2. Various characters of mat rush measured at different growth stages.

Variety	Days after planting	Plant height (cm)	Tiller number	Stem diameter (mm)	Dead stem (%)
Kang-shan 3	60	40.8	40.6	—	—
	90	49.8	78.3	—	—
	120	64.8	131.9	—	—
	150	96.2	204.8	—	—
	180	110.3	207.8	1.01	26.2
	195	110.5	209.1	1.03	26.8
	210	118.0	238.1	1.10	31.3
	225	115.5	226.2	1.10	31.3
Fs-72-p-8006	60	46.7	33.9	—	—
	90	56.5	57.3	—	—
	120	69.1	85.6	—	—
	150	102.9	138.8	—	—
	180	121.0	161.8	1.45	25.5
	195	121.9	161.5	1.48	25.9
	210	127.5	169.6	1.55	27.8
	225	121.8	162.1	1.48	29.0

(一) 株高：藺草莖長爲決定乾草品質優劣條件的因素之一，因而本研究十分著重各生育階段兩品種之株高變異。由表 2 株高項下可知，藺草植株隨生育日數之增加而增高，但自揷植後 210 日開始，反有降低之現象，此乃因生育日數太長，草莖尖端枯萎之故，此等結果正與日本岡山縣立農業試驗所之報告相同。比較四種不同收穫期顯示，兩品種並以 210 日收穫者植株最高，225 日次之，180 及 195 日最低，而對照表 1 變方分析之顯著性測定，則知各收穫期株高之差異達 5 % 顯著水準。同時中莖種 FS-72-p-8006 之有效莖長達 127.5 cm，較細莖種岡山 3 號之 118.0 cm 高 9.5 cm，品種間之差異相當顯著（表 1）。

又爲了進一步比較藺草株高在各生育階段之平均相對生長情形，仍將藺草之生育過程，以 30 日爲一區分，其相對增長情形以 $\frac{X_n - X_{n-1}}{X_{n-1}} \times 100$ %表示之，估算結果列於表 3。由表 3 得知藺草株高之增加主要發生在移植後 120～150 日之間，數據顯示揷植後 150 日時岡山 3 號之株高已達最高株高之 81.5 %；Fs-72-p-8006 則爲 80.6 %，亦即藺草揷植後 4～5 個月之間，爲株高增加最快的生長旺盛期，據此，就株高言，似可推定此時應爲藺草最適栽培管理中之一極其重要的階段。

(二) 分蘖：藺草爲高分蘖性之作物，分蘖又是影響乾草產量的最重要因子之一。有效分蘖多則產量高，反之則低。因此不同品種在不同生長階段的分蘖數變化亦待瞭解。由表 2 可得知兩品種在揷植後各個階段之增減變異。細莖種岡山 3 號在任一生育階段之分蘖均遠超過中莖種之 Fs-72-p-8006，而收穫期間之分蘖數比較，則二品種均以 210 日最多。

由表 3 分蘖數在各生育階段增長之情形可知，兩品種分蘖增加最快之時期在揷植後 60～90 日之間。而由變方分析表（表 1）中得知，藺草之分蘖表現對環境因子微氣象之變動極爲敏感。故配合前段株高之伸長變異來考慮時，藺草之生育期中，揷植後 2～3 月間及 4～5 月間爲栽培管理上一重要之時間。

(三) 莖徑與分蘖枯死率：觀表 2 莖徑與分蘖枯死率在四個收穫期之變異可知，兩品種之變化相當一致。兩品種莖徑均以揷植後 210 日收穫者略粗，分蘖枯死率岡山 3 號以揷植後 210 日達高峰

表 3. 藺草株高、分蘖於各生育期之平均增長率

Table 3. Average percent increase of plant height and tiller number of mat rush between stages, calculated based on the formula $\frac{x_n-x_{n-1}}{x_{n-1}}\times 100\%$.

Character	Between stage (days after planting)	Kang-shan 3	Fs-72-p-8006
Plant height	60-90	22.1	21.0
	90-120	30.1	22.3
	120-150	48.5	48.9
	150-180	14.7	17.6
	180-210	7.0	5.4
Tiller number	60-90	92.8	69.0
	90-120	68.5	49.4
	120-150	55.3	62.2
	150-180	1.5	16.1
	180-210	15.0	5.2

，FS-72-P-8006 則到 225 日時尚陸續枯死中，惟變方分析表（表 1 ）中顯示前述該兩性狀雖品種間之差異極顯著，但收穫期及收穫期與品種之交感則概無差異存在，此似顯示藺草產量之決定因素雖有株高，分蘖數、莖徑及分蘖枯死率，但株高和分蘖數之變異對乾草產量變異之影響較大。

三、藺草不同生育期與乾草產量及分級草量之影響

供試兩品種於四個不同收穫期之乾草產量及分級草量示於表 4 。由表 4 得知兩品種乾草收量之不同收穫期變化相當一致，分級草量之變異則兩品種迴然不同。詳言之，兩品種之乾草收量均以插植後 210 日最高，分別爲岡山 3 號 11,510 kg/ha, Fs-72-p-8006 135,80 kg/ha，插植 225 日次之，195 日再次之，以 180 日最差。就兩品種各分級草量言，細莖種岡山 3 號在任一收穫期均無一級草出現，二級草量則隨生育日數之增加而相對增加，三級草量則順序遞減。反觀中莖種 Fs-72-p-8006 在任一收穫期均有一級草出現，惟其量則依收穫日數之增加而依序遞減 。至於二級和三級草之變異則與細莖種岡山 3 號相似。故就經濟之觀點來評定兩品種之優劣時， Fs-72-p-8006 不僅較

表 4. 收穫期對乾草產量及分級草量之影響

Table 4. Influence of harvesting date on yield and grass grade.

Variety	Harvesting date (days after planting)	Dry grass yield (kg/ha)	Grass grade (%)[a]		
			I	II	III
Kang-shan 3	180	10,100	—	25.6	74.4
	195	10,470	—	25.3	74.7
	210	11,510	—	29.4	70.6
	225	10,880	—	42.5	57.5
Fs-72-p-8006	180	11,890	8.8	40.4	50.8
	195	12,360	5.6	48.4	46.0
	210	13,580	5.9	53.6	40.5
	225	13,340	1.9	56.8	41.3

a. I : length of grass over 120cm ; II : 100-119 ; III : 70-99cm

岡山 3 號高產，且任一收穫期均有一級草出現，Fs-72-p-8006 實更具推廣的價值。

四、藺草莖部橫切面之顯微觀測

藺草髓徑之大小與莖徑之大小有關，其為決定藺草彈性品質優劣之主要因子，可稱頗重要之農藝性狀之一。藺草莖部之橫切面組織，經以顯微鏡觀查結果例示於圖 1 及圖 2 。由圖中得知藺草莖部之最外層係由多層細胞組成之表皮層（epidermis）。其內有呈環狀排列之大型維管束組織 ， 其間並有較小之維管束零星散布。最內層則為髓部，佔有莖徑之大部份空間（圖 1 ）。髓部由星狀細胞（starcell）所組成，細胞呈輻射狀分枝，且彼此互相連繫（圖 2 ）

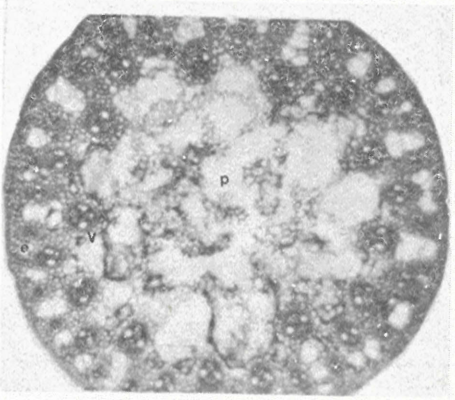

Fig. 1. Cross section of mat rush stem. e : epidermis, v : vascular bundle, p : pith (300x).

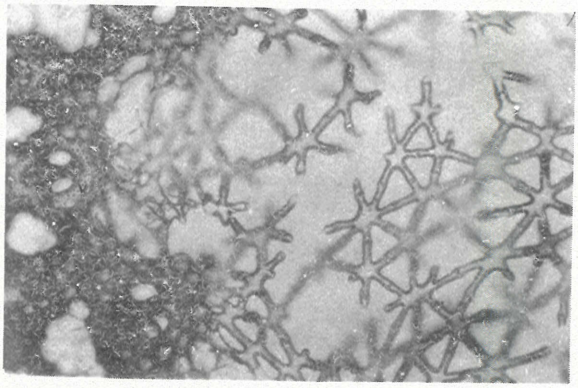

Fig. 2. The star cells of stem pith of mat rush. v : vascular bundle (1200x).

表 5. 藺草髓徑於不同收穫期觀測結果

Table 5. Pith diameter (mm) of mat rush stem measured at different growth stages.

Stem part	Kang-shan 3					Fs-72-p-8006				
	Days after planting					Days after planting				
	180	195	210	225	Average	180	195	210	225	Average
Top	0.98	1.03	1.15	1.11	1.07	1.36	1.44	1.36	1.39	1.39
Middle	1.02	1.08	1.14	1.18	1.11	1.52	1.52	1.56	1.58	1.55
Base	0.86	0.76	0.81	0.84	0.82	1.33	1.25	1.32	1.28	1.30
Average	0.95	0.96	1.03	1.04	—	1.40	1.40	1.41	1.42	—

表 5 所示係不同收穫期藺草頂部、中部與基部之髓徑大小。觀表 5 得知兩品種之髓徑皆隨生育時間之延長而有增大之趨勢 。 就品種言，岡山 3 號之髓徑介於 0.95～1.04 mm 之間，平均值為 1.00 mm；Fs-72-p-8006 介於 1.40～1.42 mm 之間，平均值為 1.41 mm。品種間之差異極大，亦即中莖種之平均髓徑比細莖種大 0.41 mm。就部位言：髓徑以中部最粗，頂部次之，基部最細，部位間之變異亦大。

表 6. 不同收穫期各部位髓徑大小之變方分析表

Table 6. Analysis of variance of pith diameter at different growth stages

S. O. V.	D. F.	S. S.	M. S.	F.	P>F
Block	3	0.0924	0.0308	0.8678	0.5056
Harvesting peroid (H)	3	0.2093	0.0608	1.9648	0.1894
Error (A)	9	0.3196	0.0355	—	—
Variety (V)	1	16.5502	16.5502	1262.7719**	0.0000
H×V	3	0.1124	0.0375	2.8596	0.0573
Stem part (S)	2	4.7699	2.3850	181.9710**	0.0000
H×S	6	0.3007	0.0501	3.8243**	0.0028
V×S	2	0.4575	0.2287	17.4517**	0.0000
H×V×S	6	0.1331	0.0222	1.6923	0.1377
Error (B)	60	0.7864	0.0131	—	—
Total	95	23.7315	—		

由表 6 不同收穫期各部位髓徑大小之變方分析中得知，各收穫期間髓徑之差異雖不顯著，但品種間髓徑之差異則極顯著。此顯示出藺草插植 180 日以後，髓徑之大小已定，亦即彈性品質屆此已趨穩定；因此若不考慮其他乾草收量等因素時，則藺草自插植 180 日後，何時收穫並不致影響到彈性品質。不同莖位與收穫期及品種之交感顯著，因此有進一步估算不同莖位與收穫期及品種個別交感值之必要（表 7 及表 8）。由表 7 顯示藺草插植後 210 天收穫期，髓徑大小與莖位之交感值均不顯著，故 210 天爲較適當之收穫期。由表 8 得知，細莖種岡山 3 號頂部之彈性品質較佳，越向基部則越差；若 Fs-72-p-8006 則反是，基部之彈性品質最佳，而越向中，頂部，則彈性品質愈趨低下，亦即兩品種彈性品質之走向剛巧相反。

表 7. 收穫期髓徑與莖不同部位髓徑之交感

Table 7. Interaction of havesting date and stem part on pith diameter.

Harvesting date (days after planting)	Stem part			
	Top	Middle	Base	Total
180	−0.0075*	−0.0082*	+0.0157**	0.0000
195	+0.0075*	−0.0006	−0.0069	0.0000
210	+0.0016	+0.0011	−0.0027	0.0000
225	−0.0016	+0.0077*	−0.0061	0.0000
Total	0.0000	0.000	0.0000	-0.0000

表 8. 品種間髓徑與莖不同部位髓徑之交感

Table 8. Interaction of varieties and stem part on pith diameter.

Variety	Stem part			
	Top	Middle	Base	Total
Kang-shan 3	+0.0113**	−0.0038	−0.0075*	0.0000
FS-72-P-8006	−0.0113**	+0.0038	+0.0075*	0.0000
Total	0.0000	0.0000	0.0000	0.0000

結　　論

綜合以上試驗結果提示：就農藝性狀分蘖及株高之表現而言，插植後 2～3 月及 4～5 月等兩個生育階段爲藺草生育期中栽培管理上之最重要階段。以乾草產量，分級草量及髓徑大小等方面之表現而言，栽培中莖種 FS-72-p-8006 之經濟收益應較細莖種岡山 3 號爲高，亦即 FS-72-p-8006 爲一值得推廣之品種。至於藺草之收穫期如在無競爭作物或不受輪作制度等其他因素之影響下，建議細莖種岡山 3 號之收穫適期爲插植後 225 日，中莖種 FS-72-p-8006 爲插植後 210 日。

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參 考 文 獻

1. 曾東海、胡敏夫・1972・藺草種植期對藺草產量之影響・臺灣農業 13(3)：141-149。
2. 賴銘立、曾東海・1978・臺灣藺草之改良及今後生產改進之途徑・科學農業 26(3-4)：91-94。
3. 熊光斗、蔡焜煌、韓青梅・亞麻不同收穫期對產量及纖維品質影響之研究・農業研究 21(4)：264-272。
4. 中野善雄・1963・いぐさ栽培に關する生態學的研究・日本廣島縣立農業試驗場報告第 14 號。
5. 中野善雄・1971・いぐさ栽培，加工，販売の實際・農山漁村發行協會，東京。
6. 西川五郎・1960・工藝作物學・農業圖書株式會社，東京。
7. 加戶輝義・1971・いぐさの形態および生態に關する研究・日本岡山縣立川上農業高等學校出版。
8. 廣島縣農政部・1968・いぐさの增收技術・日本廣島農業協會發行。
9. 農林水産技術事務局・1968 いぐさ栽培技術體系・日本農林統計協會，東京。

Influence of harvest date on the yield and quality of mat rush (Juncus effusus L. Var. decipiens, Buch)[1]

Ching-Mei Han[2]

Summary

A medium-stem line Fs-72-P-8006 and a slim-stem variety Kangshan No. 3 were tested in this experiment to seek a harvest date for high yield and good grass quality of mat rush grown in Taiwan. The above-ground portion of plants was harvested 180, 195, 210 and 225 days after planting and some important agronomic characters were investigated.

Experimental results showed that mat rush harvested at 210 days after planting produced the highest dry straw yield, plant height, tiller number and stem diameter among the four treatments for either variety. The yield of Fs-72-P-8006 and Kangshan No. 3 after 210-day growth was, respectively, 13,580 and 11,510 kg/ha. Corresponding values of plant height and stem diameter for the two varieties were 127.5cm vs. 118.0cm and 1.49mm vs. 1.06mm, respectively. The medium-stem Fs-72-P-8006 performed better than the slim-stem variety Kangshan No. 3.

No significant difference in pith diameter was found in relation of various growth durations. Average pith diameter was 1.41mm for Fs-72-P-8006 and 1.00mm for Kangshan No. 3. The former was significantly thicker than the latter.

In conclusion, a growth period of 210 to 225 days was recommended for growing mat rush in Taiwan. A shortened growth would cause lower dry straw yield and inferior grass springness and hence would lower the economic value of the crop.

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氮肥種類及施用期對藺草產量及品質影響[1]

胡 敏 夫 曾 東 海[2]

摘要：於藺草不同生育期，分別施用硫酸錏與尿素，以比較兩種氮肥對藺草生育及產量等之影響。經二年試驗結果顯示，（1）乾草重兩年綜合分析結果，各處理差異不顯著，即施用硫酸錏與尿素兩者肥效無大差異，惟施用方法可考慮以前、中期施用硫酸錏，後期施用尿素較佳。（2）藺草莖部氮素含量分析結果，各處理在不同生長期莖部含氮量均超過 2％ 以上，意謂兩種型態的氮肥，供給氮素養分均很充足。收穫後土壤殘留氮素量之測定，各處理土壤含氮量均比種植前含量高，但處理間差異極微。（3）全期施用尿素區，肥料成本比對照區（全期施用硫酸錏），每公頃可節省 2,898.30 元，但每公頃乾草重與乾草價值比對照區減產 7％或減收 15.1 ％。

藺草（*Juncus effusus* L. var. *decipins* Buch），係一種多年生草本作物，屬於燈心草科（Juncaceae），故亦名燈心草，宜生長於氣候涼爽溫度約在 20～25°C 間地方[1,10]，盛產於日本、中國與韓國等地，以日本生產量最多。據 1972 年日本藺草栽培面積統計，約在 13,000 ha 左右[2]，其國內每年消費量均需達 12 萬至 13 萬公噸[2]。其用途爲編織榻榻米（Straw mats）、花筵、草履、下馱表（Wooden clogs）及各種手工藝品等[3]，爲一種利潤優厚之農作物。本省藺草栽培之興盛，緣於近年日本高度工商業發展，農村勞力缺乏，致栽培面積從 12,282 ha 逐年降至 1977年 8,000 ha [3]，因此，日本當局除了一面採取貸款獎勵農民種植外，另一面透過私人工廠向隣近勞力低廉國家之農民引進藺苗契作，然後將成品送回其本國以滿足其國內的需要量。韓國受氣候條件限制，所生產之藺草品質較低劣，唯臺灣生產之藺草品質幾乎可與日本匹敵，因此，日本商人於民國 56 年起紛紛至本省與農民私下契作[4]，至目前本省栽培範圍已遍及全省各鄉鎮，每年栽培面積約在 1,000 ha 左右，編織草蓆工廠達 81 家[5]。本所着手研究藺草栽培始自 58 年起，起初引進藺草新品種（系），除作馴化栽培觀察外，並分別從事各種栽培法研究，經多年來研究頗有成果，其試驗結果均被農民採納，因而矯正以往一昧仿效日本栽培方法之錯誤，每公頃產量逐年增加，農民收入頗高。

藺草係一種需氮肥頗高之作物，據本所肥料試驗結果，每公頃需氮素量 600 kg [6]，由於本省肥料配給，無論水稻或雜作，每公頃申配肥料量中均配有相當數量之尿素，農民以硫酸錏不足時，常以尿素代替施用，部份農民獲得顯著增產效果，但據日本藺草栽培技培技術體系記載，藺草單用尿素時脫氮現象較多肥效差[9]，另據李蘭帝等尿素肥料施肥法試驗報告，分別施用硫酸錏與尿素於稻田中，不見有顯著差異[7]。臺灣氣候土質與日本不同，施用尿素是否亦會引起嚴重脫氮現象，實需探究。乃於 65 年起進行本項試驗，以探討尿素肥料在藺草栽培施用上之可替代性。茲就二年之試驗結

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1. 臺灣省農業試驗所 研究報告 第 933 號 。本試驗第一年植體分析工作蒙臺糖公司北港糖廠檢驗課分析，第二年土壤含氮量測定及植體分析工作請本室曾金盆小姐協助，文成後蒙謝博士順景、邱技正善美斧正，特此誌謝。
2. 本所農藝系技佐、技士、臺灣省 臺中縣 霧峰鄉。

果加以整理，草成報告以祈方家指正並供農民參考。

材料與方法

本試驗係以藺草岡山 3 號爲供試材料，採用逢機完全區集設計，重複 4 次，行株距 20×20cm，行長 4 m，區寬 1.6 m，8 行區，小區面積 6.4 m^2，每公頃三要素肥料量 N 600 kg、P_2O_5 100kg、K_2O 90 kg，氮肥種類及施用期分爲：(A) 全期施用硫酸錏(CK)，(B)全期施用尿素，(C) 前、中期施用硫酸錏，後期施用尿素，(D) 前期施用硫酸錏，中、後期施用尿素，(E) 前、中期施用尿素，後期施用硫酸錏，(F) 前期施用尿素，中、後期施用硫酸錏等六處理，前期係指插植後 120 天，中期 120～150 天，後期爲 150～180 天。於八月上旬育苗，12 月上旬插植，各試區間均使用塑膠板隔開，以避免肥料混流或流失，同時在種植前與收穫後分別測定土壤含氮量，按期調查其株高，分蘖數、莖部含氮量，乾草重，品質、分級草量所佔百分率，乾草價值及枯死率等。

結果與討論

一、氮素施用時期對藺草生育之影響

表 1. 氮素施用時期對藺草農藝性狀之影響

Table1. Effecst of nitrogen fertilizer application time on plant height and tiller number in mat rush

處理 Treatment [a]	株高 Plant Height (cm)					分蘖數（支／欉）Number of tiller per plant					枯死率 (%) Percentage of dead stems
	生育日數 Days after planting					生育日數 Days after planting					
	60	90	120	150	200	60	90	120	150	200	
A	38.90	44.20	68.00	92.00	120.80	30.10	64.50	145.20	221.50	227.00	27.1
B	37.30	42.60	66.70	90.00	119.90	32.40	66.60	145.20	207.60	215.00	25.7
C	38.10	44.80	68.10	91.50	119.30	29.20	67.60	147.70	219.20	230.00	23.5
D	38.40	41.20	67.10	90.70	117.40	30.00	67.60	146.20	180.70	212.00	29.5
E	38.30	43.10	67.50	89.60	119.30	30.90	60.40	143.40	219.20	241.00	27.3
F	38.30	44.90	66.20	89.60	117.00	30.90	64.80	140.30	212.00	244.00	22.6

a. 參閱材料與方法。

株高、分蘖數及枯死率等爲決定藺草產量與乾草價值之重要因素，探究各處理間植株生長速度勢屬必要，經作各處理相互間之比較（表 1）或變方分析，發現株高在各不同生長日數時數字相近，而分蘖數處理間實測 F 值 0.27＜5 % 理論 F 值 2.53 無顯著差異，由此可確定尿素與硫酸錏對藺草之發育肥效相近。至於枯死率，各處理均達 20 % 以上，似有偏高之趨勢，此乃由於品種之特性，或呈退化現象，所導致之結果，其原因尙待進一步之研究。

二、氮素施用與植體含氮量之關係

測定各處理在不同生長階段之莖部含氮量、與種植前、收穫後之土壤含氮量，以了解藺草對兩種型態之氮肥吸收情形。通常藺草生長盛期在 4、5、6 月，因之植體取樣於 4 月上旬、5 月上旬、6 月上旬等三期行之。取樣時爲期正確起見，植體樣品應包含新舊藺草植株，每期每處理各取二樣品，三期計採 36 樣品，經晒乾細碎後，每樣品各取 0.4 g 以克氏 (Kgeal dahl's) 全氮定量法測定莖部含氮量。種植前土壤取樣，於預定試驗田之四隅及中央各取一樣品計五樣品。種植後之土壤取樣，係每處理選二試區，各取一樣品，六處理共取 12 樣品，分別涼乾後亦以克氏全氮定量法測定土

壤中含氮量，以作比較，其測定結果詳如表 2 及圖 1 。

表 2. 各處理於不同生長期莖部含氮量

Table 2. Nitrogen content in stems of mat rush at the different growing periods

處 理 Treatment	莖部含氮量 (%) Nitrogen content		
	Days after Planting		
	120	150	180
A	2.50[a]	2.53	2.22
B	2.50	2.56	2.23
C	2.41	2.41	2.02
D	2.51	2.55	2.24
E	2.39	2.47	2.08
F	2.57	2.55	2.23

a. 四重複之平均數。 mean value of four replications.

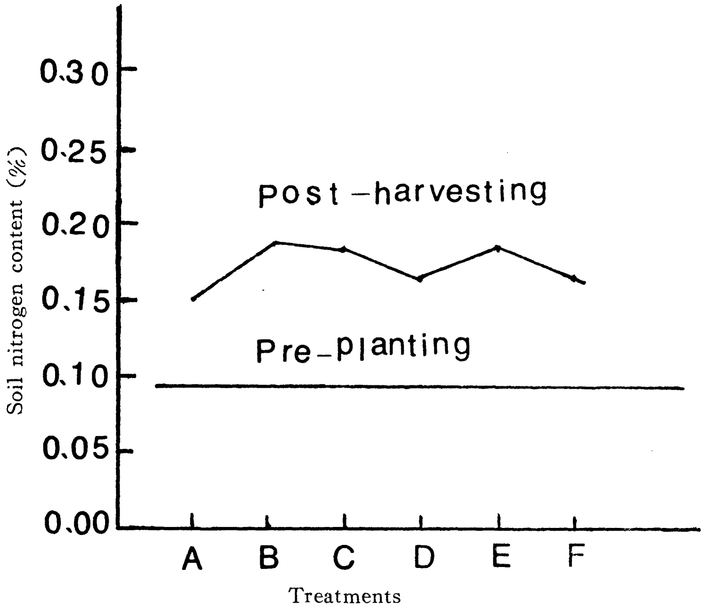

圖 1. 各處理種植前、後土壤中含氮量比較

Fig 1. A comparison of nitrogen content in soil at pre-planting and post-harvesting times

依據 1971 糖試所報告，甘蔗正一葉片含氮量可爲氮素養分供給與否之指標，不論土壤與氣候條件若何，於生長盛期氮素含量高於 2 %，即顯示氮素養分之供量已足 (8) 。如此，從表 2 中資料得悉，各處理莖部含氮量平均亦達 2 % 以上，顯然兩種不同型態之氮肥，均已足量供給藺草吸收，在肥效比較上無顯著差異，且比日本廣島縣農試所所報告資料爲高 (11) ，此又可確定本省藺草田施用尿素之肥效比日本爲佳。土壤含氮量之測定，在種植前爲 0.093 %， 收穫後各處理土壤含氮量分別爲 (A) 0.15%、(B) 0.175%、(C) 0.17%、 (D) 0.16%、 (E) 0.175%、 (F) 0.16 %，即收穫

後各處理土壤含氮量均較種植前高，而此殘留量處理間差異極微（如圖1）。

三、各處理氮素肥料成本之比較

表 3. 各處理施用氮肥成本之比較

Table 3. The cost analysis of two nitrogen fertilizers applied in different treatments

處 理 Treatment	肥料成本額（元／ha） cost（NTdollar/ha）	差 異 Difference(NTdollar/ha)	備 註 Remark
A	10,828.40		（1）硫酸銨，每公頃需要量爲 2,857.10 kg，每 kg 3.79元計算。
B	7,930.10	+ 2,898.30	
C	9,862.40	+ 966.00	（2）尿素，公頃需要量爲1,304.30 kg ，每 kg 6.08元計算。
D	8,986.30	+ 1,932.10	
E	8,896.30	+ 1,932.10	（3）前期、中期、後期所需肥料量按各處理不同，各以⅓氮素量互爲變換。
F	9,862.40	+ 966.00	

一般藺草田全期施用硫酸銨，每公頃需氮肥成本 10,828.40 元，全期施用尿素僅需 7,930.10元，兩者相比，後者可節省 2,898.30 元，若以⅓氮素量分別在前 、中及後期互換施用 ，則可各節省 966 元與 1,932.10 元（如表3），如此就肥料成本言，施用尿素直接可節省生產成本，但就產量與乾草價值論，最佳氮肥施用法仍以後期配合⅓氮素量施用尿素爲佳。

四、各處理公頃乾草重及乾草價值

經調查及估算結果，如表 4 及圖 2 。

表 4. 處理間乾草重與乾草價值之比較

Table 4. Comparison of dry weight and value of grass among different treatments

處 理 Treatment	乾 草 量[a] Dry weight (kg/ha)	指 數 Index (%)	分 級 草 量(%) Grade of grass 1 級[a] First grade	 2 級[a] Second grade	 3 級[a] Third grade	品 質 Color ard laster	乾 草 價 值[b] Value of grass (N. T. dollar/ha)	指數 Index (%)
A	10,873.50	100	5.79	36.15	58.06	優 Good	158,149.40	100
B	10,146.10	93	5.10	23.85	71.05	優 Good	134,199.80	84.9
C	11,348.50	104	5.98	34.90	59.13	優 Good	164,232.40	104
D	10,057.10	92	6.15	28.90	64.95	優 Good	140,425.80	89
E	10,268.80	94	3.05	26.85	69.80	優 Good	135,519.60	86
F	10,205.50	94	4.13	37.65	58.23	優 Good	147,144.60	93

a. 兩年平均乾草產量及 1 級草 120 cm 以上，2 級草 100-119 cm ，3 級草 70-99 cm.
Average of two years. First grade : more than I20 cm. Second grade : 100-119 cm and Third grade : 70-99 cm.

b. 1 級草每公斤 26 元，2 級草每公斤 20 元，3 級草每公斤 10 元。
The estimated comercial value of mat rush : First grade : 26 N. T. dollar/kg ; Second grade : 20 N. T. dollar/kg ; Third grade : 10 N. T. dollar/kg.

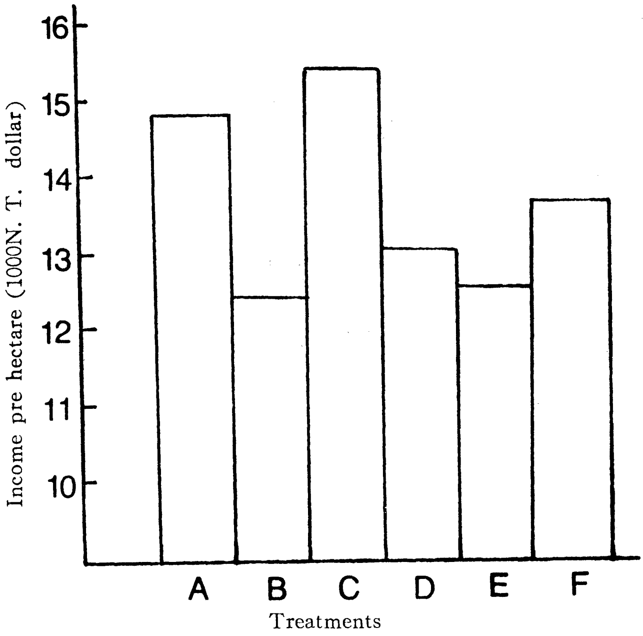

圖 2. 各處理乾草價值之比較。

Fig 2. A comparison of comercial value of mat rush among treatments

自表 4 及圖 2 顯示，公頃平均乾草重及乾草價值，以 C 處理最高比對照區 A 處理增產或增收 4 %，全期施用尿素區，則比對照區減產 7 % 或減收 15.1 %，其他處理亦較對照區低，顯示藺草栽培後期配合施用⅓氮素量之尿素肥料，對藺草之生長比全期施用硫酸錏較佳。

五、各處理乾草產量綜合分析

表 5. 乾草重綜合分析 (1977年和1979年)

Table 5. Analysis of variance for dry weight (1977 and 1979)

變 因 Source of Variation	自 由 度 d. f.	平 方 和 S. S.	均 方 M. S.	實 測 F 值	理論 F 值 5 %	 1 %
年 度 (L)	1	2.014	2.014	5.59*	4.17	7.56
區 集 (B)	6	14.73	2.455	4.09		
處 理 (t)	5	4.34	0.88	2.44	2.53	
L × t	5	3.88	0.776	2.155	2.53	
機 差 (E)	30	10.96	0.36			
總 計 (Total)	47					

從上表得知，年度實測 F 值為 5.59>5 %理論 F 值 4.17 呈顯著，此乃顯示兩年間氣候變動差異所致。處理間實測 F 值 2.44<5 %理論 F 值 2.53，差異呈不顯著，即各處理間之產量差異不大。年度與處理之交感效應亦呈不顯著，此顯示各處理受年度不同未有顯著的差異。

結 論

尿素為一濃厚之氮素肥料，不含有害之副成分，雖連年施用不致使土壤劣變，又在土壤中變化為碳酸銨後，即可為土壤吸着吸收利用[9]。據日本廣島縣農業試驗場報告[11]，藺草生育後期施用氮素

肥料多量殘留土壤時，能使後作水稻發生稻熱病（Rice Blast），而尿素係屬速性肥料，施用後短時間內較硫酸錏能被吸收，因之藺草栽培施用尿素頗具研究價值。綜觀上述試驗結果，藺草栽培施肥法、全期施用尿素雖每公頃可節省肥料成本 2,898.30 元，但其乾草重與乾草價值比對照區減產 7 %或減收 15.1 %，不宜採行，但如在生長後期將其 ⅓ 之氮素量以尿素施用則比對照區增產與增收 4 %。植體含氮量分析結果顯示，尿素施用於藺草田之肥效不比硫酸錏差，此結果與前人試驗結果[7]相埒。

參考文獻

1. 曾東海、胡敏夫・1977・藺草種植期對藺草產量之影響・臺灣農業 13(3)：141-149。
2. 許水田・1972・日本圓藺草栽培技術考察報告書。（油印本）。
3. 賴銘立、曾東海・1978・臺灣藺草之改良及今後生產改進之途徑・科學農業 26(3-4)：91-94。
4. 臺灣省農會・圓藺草簡報資料。（油印本）。
5. 蓆業同業聯誼會・1978・蓆業同業名册。（油印本）。
6. 賴銘立、曾東海、李雨霖等・1977・肥料用量對藺草產量及品質之影響。（未發表）。
7. 李蘭蒂、林金標、林國謙、徐水泉等・1960・尿素肥料施肥法試驗成績（第二報）・農業研究 9(2)：20-31。
8. 陳正義、胡崇理等・1971・氮素施用時期與甘蔗可製糖率及氮素養分吸收關係，糖試所研究彙報 54：67-76。
9. 包伯度・1972・肥料學。：121-128。國立編譯館出版。
10. 農林統計協會・1968・水田作いぐさ栽培技術體系，No. 21：62-63。
11. 中野善雄・1963・いぐさ栽培に關する生態學的研究，廣島縣立農業試驗場報告 14：10-26、75-76。

Effects of different nitrogen fertilizers and time of application of the yield and quality of mat rush (*Juncus effusus* L. var. *decipiens*, Buch)

M. F. Hu and T. H. Teseng

Summary

The present experiment was conducted to study the effects of two nitrogen fertilizers on the yield and quality of mat rush over two years (1977 and 1979) . The results are summarized in the following :

1. No significant difference in fertilizer response was observed in term of dry weight of the glass between two kinds of fertilizers. However, for good management of fertilizer application, it is suggested to apply ammonium sulphate at the early stage and urea at the later stage of growth.

2. There was no significant difference in nitrogen content in the straw measured at the different growing stage between two fertilizer treatments, the value obtained being around 2%.

3. It was estimated that the plot applied with urea costs 2898.30 N. T. dollar less than that applied with ammonium sulphate. In parallel to this, the yield of dry starw was also reduced up to 7 % which is equivalent to 15.1% reduction in commercial value.

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